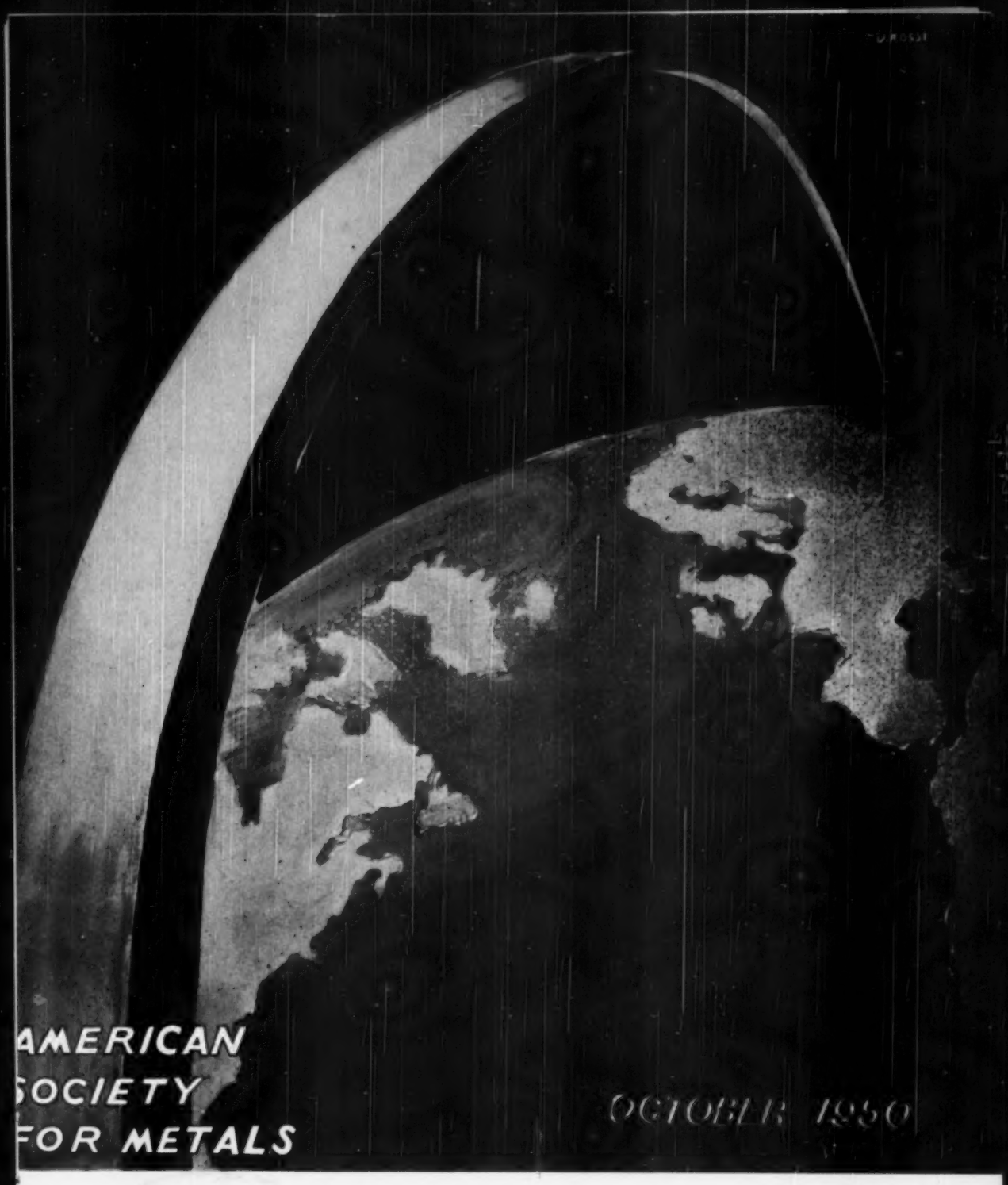


AMERICAN
SOCIETY
FOR METALS

OCTOBER 1950

METAL PROGRESS

Heat Treat REVIEW

. . . all the Latest 'Surface' Advancements in Equipment for Heat Treating

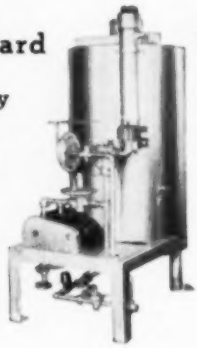
Again, 'Surface' will bring to the National Metal Exposition complete information on the most recent developments in equipment for *all modern heat treating processes.* Here will be represented the most efficient of furnace equipment with operating characteristics to meet the requirements of any specific heat treating job . . . whether it be for motor cars or munitions; home freezers or military tanks. Production capacities are available to meet the requirements of the situation.

'Surface' Industrial Furnace Engineers will be available at all times to answer questions and be helpful in supplying information on special and standard furnaces, prepared atmosphere generators, or industrial gas-burner equipment.

NEW Standard MRX Generator

800 cfh. capacity

See it on display at the 'Surface' Booth



MRX Generators produce an RX Gas Atmosphere by the catalytic cracking of a mixture of air and hydrocarbon gas at high temperature. This gives an excellent base gas for clean hardening, carbon restoration, gas carburizing and dry cyaniding of carbon and alloy steels.

MRX and RX are trademarks of Surface Combustion Corporation.

SPECIAL PROCESSES AND EQUIPMENT

Gas Carburizing
Carbon Restoration (Skin Recovery)
Suspended Carburization
Homogeneous Carburization
Dry (Gas) Cyaniding
Clean and Bright Atmosphere Hardening
Bright Gas Normalizing and Annealing
Bright Super-fast Gas Quenching
Atmosphere Malleableizing
Atmosphere Heating for Forging
High Speed Heating for Forging

•

Prepared Gas Atmosphere Generators

STANDARD RATED INDUSTRIAL FURNACES

Large Oven Furnaces
Small Oven Furnaces
Forging Furnaces
"Balco" and "Charmo"
Atmosphere Furnaces
Muffle Furnaces
Pot and Crucible Furnaces
Forced Air Convection Furnaces
Air Heaters

GAS-FIRED INDUSTRIAL BURNERS

High and Low Pressure—Over 60 Types . . . 600 Sizes

Burner-Inspirator Units
Burner Nozzles
Inspirators
Tubular Heating Equipment
Atmospheric Type Burners
Gas-Oil Burner Equipment

•

'Surface' cordially invites you to "heat treat headquarters" at the National Metal Exposition.

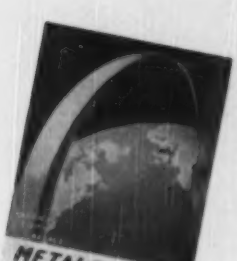
BOOTH 1106
Main Arena
International Amphitheatre
Chicago
NATIONAL METAL EXPOSITION
October 23 through 27

GET ALL THE PARTICULARS AT

'Surface'

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

THIS ISSUE



Metal Congress 468

Annual Convention of the Society

Consolidated program . . . details of the meetings

METALLURGICAL INVENTORY

How are we doing in the Korean year?

Copper and Brass 472

A revolution is all but completed

Metal Science 478

A valiant effort to take up slack

Aluminum 484

Four times the 1939 activity

Alloy Steels 491

Away from autos into general industry

Foundries 499

Mechanically adequate; metallurgically advancing

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The bottleneck in jet engines

Magnesium 512

Production and fabrication skills now adequate for rapid expansion

Bessemer Steel 519

The old girl should display her charms

Complete Table of Contents on p. 465

Flip the Flap→

As I was saying—

I'LL HAVE TO TALK A LOT to fill this space in each issue of METAL PROGRESS. And I have to be careful what I say to you 20,000 ASMembers (sh, there are ladies present!). But I can't let a column slay me. I've been talking to you for 32 years and haven't run down yet!

Speaking of 32 — that reminds me this month's mammoth edition of M.P. is in recognition of the 32nd Annual Convention and Exposition of the ● (and thanks to those wide-awake advertising and business men for over 175 pages of pertinent advertisements — so why not when making purchases tell them you saw their ad in *your own* magazine, "Metal Progress"?).

It all started in 1918 when Arthur G. Henry, first secretary of the Chicago chapter and a founder member of A.S.M., returned from a Foundry Show in Milwaukee all enthused with the idea that the A.S.M. should have the first heat treating show ever held in the world. So the newly elected business manager (now the National Secretary) had placed on his shoulders the responsibility for this first-time event.

Gee, how we did stew about that first show (and we still stew to cook up a delectable Congress and Exposition), and in spite of inexperience the impression created by the 53 exhibitors was quite remarkable. It was a new method of advertising for all of them but they gave a swell performance and delighted the 10,000 visitors. The 72 technical papers presented at the 7th Regiment Armory, where the show was held, constitute Volume II of the *Journal* of the American Society for Steel Treating.

The Iron Age in reporting the meeting said "The sensation of the week!", "Keep your eyes on that young group", and so on.

If you count to go to sleep, from one to 32 is a short run but it is a long time in years. Some of the original 53 exhibitors have vanished from the scene, but here is a list of the Old Faithfuls — they were all in the first and are in the 32nd show as well:

American Gas Furnace Co.
Brown Instrument Co.
A. Finkl & Sons Co.
Claud S. Gordon Co.
E. F. Houghton & Co.
Leeds & Northrup Co.
People's Gas Light & Coke Co.
Q-Alloys
Surface Combustion Corp.

Hope to see all of you in Chicago, October 23rd to 27th, 1950.

Cordially,

Bill

W. H. Eisenman, Secretary
American Society for Metals

HIGH PRODUCTION *in an* EMERGENCY

THE METAL INDUSTRY is awake to the need for increased production. It will meet the challenge as it has done in the past.

The 32nd Annual National Metal Congress and Exposition comes at a most appropriate time. At this all-important meeting of the top management, production and engineering talent in the industry, more than 30,000 will be in attendance.

If you haven't already planned to be in Chicago for the Metal Congress and Exposition—do so NOW! You will gain much by meeting people in the industry with similar problems—by seeing first hand what's new and improved to aid you in increasing your production.

This will be one of the most important meetings in the history of the metal industry. Top management men will be able to meet and talk to others—to compare notes, and to gather helpful information that would take weeks to secure in any other manner. And that goes for production men—department managers, supervisors, superintendents and foremen. All will be looking and listening—to get as much information as possible in a short space of time. And time is important right now. Engineers and metallurgists will be there to see what's new in equipment and processes, to examine and learn about structure and properties of new materials, that will fit into their operations and enable them to quickly step up production.

There will be about 400 firms displaying their products and services, with trained men in attendance to answer your questions and explain how they can help you achieve HIGH PRODUCTION.

Four great societies sponsor and participate in the Metal Congress and Exposition.

The American Welding Society will hold technical sessions at the Sherman Hotel, Monday through Friday.

The Institute of Metals Division of A.I.M.E. will hold technical sessions Monday, Tuesday and Wednesday at the Sheraton Hotel.

The Society for Non-Destructive Testing will hold technical sessions on Tuesday, Wednesday and Thursday at the Morrison Hotel.

The American Society for Metals has a full week—Saturday through Friday—of technical sessions to be held at the Palmer House. "High Production" Sessions will be held at The Amphitheatre. If you would like a complete program of the Metal Congress, write American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio.

Chicago is centrally located and within reach of the entire metal industry. Plan now to attend this great meeting. There are ample hotel accommodations—write Chicago Convention Bureau, Inc., 33 N. LaSalle Street, Chicago 2, Ill.

Attend the Metal Congress and Exposition and you'll take back information that will enable you to do your job better and help your company do its share in this emergency.

Latrobe's New Steel
For Longer Die Life!

Latrobe's BR-4 high vanadium, high chromium die steel, with its greater number of evenly dispersed vanadium carbides, is "a bear for wear"—developed expressly for use where superior abrasive resistant qualities are demanded.

Die makers and users throughout industry have found that BR-4 results in longer production runs and decreases die costs . . . that it actually outlasts other types of die steels by at least 2 to 1 on jobs where abrasion is a problem.

Learn how BR-4 can lengthen die life and decrease unit production costs for you . . . Consult your LATROBE SERVICE ENGINEER!

Latrobe's Desegatized Brand Steels are noted for full structural uniformity as a result of evenly dispersed carbide particles throughout the steel cross-section.

For extra toughness, greater wear resistance, and ease in machining and heat treating — always specify LATROBE DESEGATIZED BRAND STEELS.

LATROBE ELECTRIC STEEL COMPANY

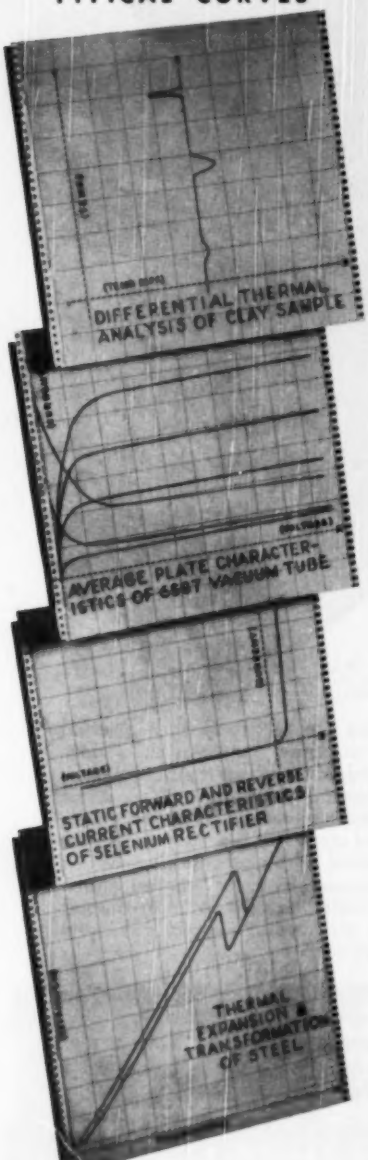
LATROBE, PENNSYLVANIA

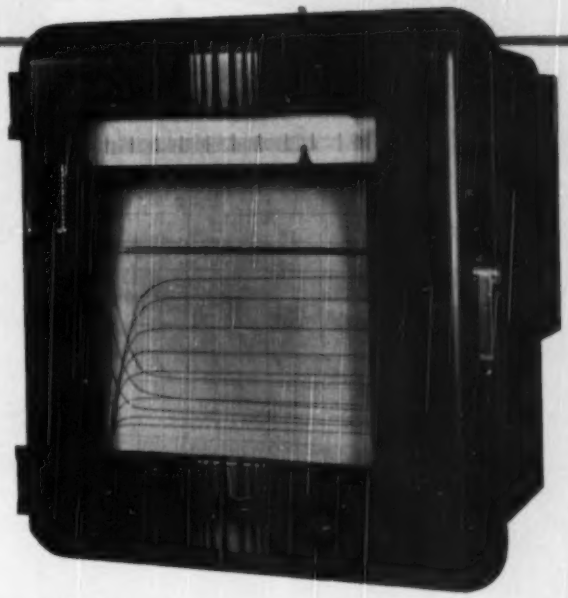
BRANCH OFFICES AND WAREHOUSES

*TRADE MARK REGISTERED U. S. PAT. OFFICE

Now you can plot X vs. Y...automatically

TYPICAL CURVES


DIFFERENTIAL THERMAL ANALYSIS OF CLAY SAMPLE
AVERAGE PLATE CHARACTERISTICS OF 6SB7 VACUUM TUBE
STATIC FORWARD AND REVERSE CURRENT CHARACTERISTICS OF SELENIUM RECTIFIER
THERMAL EXPANSION & TRANSFORMATION OF STEEL



with the

New Speedomax 2-Function Recorder

Boon to engineering and research laboratories, this new Speedomax Recorder automatically plots a continuous, accurate curve showing the relationship between any two variables brought to the instrument in the form of d-c signals. Gone are those hours of tedious compilation and point-by-point plotting of data.

Just glance at these typical curves and note the instrument's remarkable versatility. Its big 10" chart provides remarkably complete detail. Potential applications are as broad as a researcher's imagination.

This new X-Y Recorder has *two* electronic circuits, one for each function. X corresponds to horizontal pen travel; Y to up-and-down movement of the chart. Input voltage can be as low as 2.5 mv for X; 10 mv for Y. Response time is amply fast—just 2 sec for full scale pen travel (X); 4 sec per 10" of chart (Y).

For details, send for Folder EM9-420(1). Write us at 4927 Stenton Ave., Philadelphia 44, Pa.

Jrl Ad EM9-420(2)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Metal Progress is published and copyrighted, 1950, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

The NEW MOTCH & MERRYWEATHER No. 00-G Circular Sawing Machine

No. 00-G automatic model has air-operated stock feed for standard lengths up to 24".

Insert jaws of desired angle permit precision cut-off of stock up to 45° angle.

NOW, for the first time on a circular sawing machine, you can do square and angular cutting up to 45° of ferrous or non-ferrous stock up to 3" round or square, *fast and accurately.* The rugged one-piece saw head is gravity fed; speed changes by pick-off gears. Automatic stock feed for high production; manual feed for smaller shops and tool rooms. Special fixtures for odd-shaped parts. *Let us figure how much we can save you* on that next difficult job.

Write today for Bulletin 00-G.

Manufactured by

THE MOTCH & MERRYWEATHER MACHINERY COMPANY
715 PENTON BUILDING • CLEVELAND 13, OHIO
Builders of Circular Sawing Equipment, Production Milling, Automatic and Special Machines

PRODUCTION-WITH-ACCURACY MACHINES AND EQUIPMENT

Think of FINKL

FOR THE *FINEST* FORGINGS

This is a 14,560 pound hydraulic steering ram for an ocean going passenger liner. It started as a 54" ingot of SAE 1045 steel weighing 54 tons. In the skilled hands of Finkl craftsmen, it was heated and forged; iso-thermally annealed; fully annealed; preliminary rough machined; heat treated and then final rough machined. When shipped it was 16'2" long with an O.D. of 26" and a 21½" bore.

As with all Finkl jobs, skilled and experienced men take nothing for granted. Each step is carefully planned and checked. The most modern methods and machinery are employed to create these Finkl forgings. The most up-to-date heat treating shops and testing equipment as well as laboratory procedures guarantee the best steel for the job and the best job from the steel.

Finkl engineers know steel and its application. Their knowledge and suggestions are available to you. Call or write when you want to talk forgings.

A. Finkl & Sons Co.

2011 SOUTHPORT AVENUE • CHICAGO 14

DIE BLOCKS & INSERTS • PISTON RODS & RAMS • SOW BLOCKS • CRANKSHAFTS

Laboratory Tests Dictate Choice of Alcoa Aluminum Fasteners by American Seating Company

(Above) Polo Grounds, home of the New York Giants, where seating was installed by American Seating Company. Alcoa Aluminum Bolts and Nuts are used exclusively on these seats. (Right) A typical stadium chair manufactured by American and the type of Alcoa Fastener used in it.

AMERICAN SEATING COMPANY
Grand Rapids, Michigan

Testing Laboratory Report

Research Division

Date 4-6-50

To: Mr. G. H. Roterick

From: Mr. L. J. Czechorski

Subject: CORROSION RESISTANT BOLTS AND NUTS

1. Attached are laboratory reports showing the results of corrosion and strength tests on alloy bolts and nuts for our stadium chairs.

2. These reports show that aluminum bolts and nuts, made of 24 S-T4 Alcoa aluminum alloy satisfactorily passed all corrosion and strength tests. The test atmosphere used compared with the worst industrial atmosphere in the country. The strength requirements were established by dead load and impact testing.

3. It is [illegible] that aluminum alloy bolts and nuts be used on stadium chairs in places where plated steel parts have been standard.

L. J. Czechorski
Test Analyst

cl

WRITE FOR SAMPLES—Got a corrosion problem? Get Alcoa Aluminum Fasteners and get rid of it! We'll be glad to send you samples of the types and sizes you're interested in. Just write ALUMINUM COMPANY OF AMERICA, 2135K Gulf Building, Pittsburgh 19, Pennsylvania.

For local source of Alcoa Fasteners and other Alcoa Products, look under "Aluminum" in your classified telephone directory.

THE LOWEST-COST CORROSION RESISTANT FASTENERS ARE

ALCOA *Aluminum* FASTENERS

Complete Line of Aluminum Fasteners Offered by ALCOA

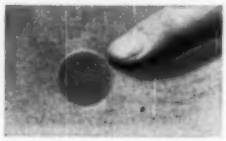
To meet the growing demand for low-cost, corrosion-resistant fasteners, the Aluminum Company of America is making and marketing a full line of aluminum fasteners. Savings ranging as high as 50% and more on some types and sizes have been reported by users who have switched to aluminum fasteners from other corrosion-resistant materials.

The Alcoa line includes sheet metal, machine and wood screws with choice of slotted or Phillips recessed head; bolts and nuts of all popular sizes; cap, castle and wing nuts; washers, rivets and cotter pins. Also a considerable line of specialty items.

Samples are offered free upon request.

"Invisible" Fastening

The Alcoa Finishing Head machine screw can often be used to simplify construction in assemblies where an invisible fastening is desired.



After the screw is driven, the raised rectangular key is sheared off. Then the screw head and surrounding area are ground and polished.

Particularly in making up assemblies of aluminum, aluminum fasteners should be used to prevent the galvanic corrosion that can result when dissimilar metals are in contact. The Alcoa Fasteners have the further value of providing close color match with surrounding aluminum surfaces. They eliminate disfiguring red rust streaks.

Dress Up Assemblies

Radio cabinets and similar wood and plastic products can be dressed up by attractive, corrosion-resistant Alcoa Aluminum Wood Screws at suprisingly little additional cost. Alcoa Wood Screws are available with Phillips recessed heads which guard against driver slippage, reduce rejects. Samples of Alcoa Fasteners in the types and sizes you are interested in will be sent free upon request.

Peak Efficiency either Gas or Oil with North American Dual-Fuel* Burners

THE LINE IS *Complete*.....SELECT

THE BURNER YOUR OPERATING CONDITIONS REQUIRE

113—Long Flames. **220-221**—Short Flames, sealed-in mountings. **225**—For rugged duty, open or closed mounting, gas at zero. **232**—Compressed air atomizing oil inserts. **260**—Oiltogas Converter for burning oil as a gas in existing gas burners.

*Dual-Fuel: The North American name for burners designed especially for both gas and oil. Fuel changed by merely turning valves.

[redacted]

REPUBLIC Alloy Steels

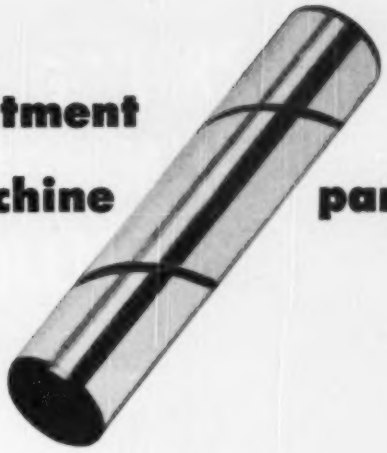
Photo Courtesy Easy Washing Machine Corporation

3-DIMENSION Metallurgical Service

. . . combines the extensive experience and coordinated abilities of Republic's *Field, Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage . . . IT CAN DO THE SAME FOR YOU.

Other Republic Products Include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire,

save expensive heat treatment of this vital washing machine part



A REPORT FROM REPUBLIC STEEL'S *alloy* METALLURGICAL FILES

When the chief metallurgist of a leading washing machine manufacturer found it necessary to improve a small but vitally important part of his company's product, he did something about it—fast. He called for a Republic Alloy Steel Metallurgist to work with him in finding a better material which would not increase production costs.

The part—a segment gear stud—was being made of a standard carbon steel analysis and required cyanide hardening to meet necessary physical requirements. This type of hardening treatment was both slow and costly . . . rejects were numerous. After careful study, it was decided to change to one of Republic's carbon-corrected cold drawn alloy steel bar analyses.

THE RESULT: An ordinary controlled atmosphere furnace treatment replaced the expensive cyanide hardening operation . . . cost savings were substantial . . . rejection losses were effectively reduced.

Putting the right steel to work in the right place—*the full purpose of Republic's 3-Dimension Metallurgical Service*—has helped countless manufacturers in the never-ending drive toward higher quality at lower cost. Would you like it to do the same for you? Write today to:

REPUBLIC STEEL CORPORATION • Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO Export Department: Chrysler Building, New York 17, N.Y.

Republic REPUBLIC STEEL ALLOY STEELS

Pig Iron, Bolts and Nuts, Tubing

a cyclone was the hit of the show!

Back in '35 at the Amphitheatre in Chicago, Lindberg's CYCLONE Furnace was the hit of the show . . . because it brought to every heat treater a *new and better way to do his job!* The CYCLONE Furnace—our first product, was the first practical 100% forced convection furnace. It represents a basic improvement in existing equipment—it has never been successfully imitated.

Through the years we have grown in size and in the scope of the products we produce. We will have the products of eight divisions on display at this year's show—many of these products representing basic improvements in the tools of your trade.

on display:

HEAT TREATING FURNACES
MELTING FURNACES
HIGH FREQUENCY EQUIPMENT
ELECTRICAL EQUIPMENT
LABORATORY EQUIPMENT
AIR & HYDRAULIC EQUIPMENT
FABRICATION
AUTO ACCESSORIES

Be sure to see our exhibit—Booth #1204—National Metal Congress, Amphitheatre, Chicago, October 23—27, 1950

LINDBERG ENGINEERING COMPANY

2448 W. Hubbard Street • Chicago 12, Illinois

Electro FIELD ENGINEERS HELP PRODUCTION MEN SOLVE PROBLEMS

GRANT S. DIAMOND
PRESIDENT

Never hesitate to write, wire, phone or drop in to see us because of fear that we'll try to sell you something.

We believe that sales will take care of themselves if we help production men to solve their problems. Warrant for holding fast to that belief is found in the record of growth of our corporation and of the contributions we have made to the metal industries.

"Electro" salesmen are actually a staff of Field Engineers. First by right of technical institution education, plussed by special training in our laboratories and/or plants, which is plussed again by our experience on problem-solving assignments in industry. Second, by right of field work.

Please remember this: "Electro" will send a Field Engineer to help you with any production problem in which our products might be helpful . . . and he won't try to sell you anything. If you want to buy something he'll gladly take your order . . . but that is something else.

Electro SINCE 1919

HIGH-SPEED GRINDING WHEELS
•
CRUCIBLES
•
REFRACTORIES Standard And Special Shapes
•
STOPPER HEADS
•
Electro-Carb BRIQUETS For Deoxidation of Metal
•
POROUS MEDIA
•
ELECTRO-CARB (Silicon Carbide) ABRASIVE GRAIN

By the way . . .

if you haven't one, let us send you free a copy of our "Grinding Wheel Manual," illustrated in full color and packed with information. Also, let us send free a copy of our new Bulletin S-750 about our newest STOPPER HEADS that eliminate many troubles including internal leakage-source cracks.

ELECTRO REFRACTORIES & ALLOYS CORPORATION
344 DELAWARE AVE., BUFFALO 2, N. Y. (Warehouse, Los Angeles)

Electro HIGH-SPEED RESIN-BONDED GRINDING WHEELS

for tougher, lighter gondolas

YOLOY steel plays an important part in the Union Pacific Railroad's 1950 car renovation program. Approximately 500 rusty, road-worn gondolas already have been given new life and restored to useful service. All drop doors, which are subjected to severe abrasion and corrosion, are fabricated from Yoloy steel plates.

Yoloy is Youngstown's high tensile low-alloy nickel-copper steel. It has demonstrated a remarkable ability to resist corrosion, abrasion, vibration and shock, even at extreme low temperatures. It also saves weight, due to its extra toughness and strength, welds readily and fabricates easily. It has proved itself in 15 years of service in railroad passenger coaches, box cars, gondolas and other heavy duty equipment.

If you are not yet familiar with Yoloy, ask us for further information. Our District Sales Office nearest you is ready to serve you promptly.

Photographs by courtesy of the Omaha shops of the Union Pacific Railroad.

Youngstown
YOLOY STEEL

THE YOUNGSTOWN SHEET AND TUBE COMPANY — General Offices — Youngstown 1, Ohio

Manufacturers of Carbon, Alloy and Yoloy Steel — Export Office - 500 Fifth Avenue, New York

SHEETS · PLATES · WIRE · ELECTROLYTIC TIN PLATE · COKE TIN PLATE · RAILROAD TRACK SPIKES · CONDUIT · PIPE AND TUBULAR PRODUCTS · BARS · RODS · COLD FINISHED CARBON AND ALLOY BARS

How to Eliminate "Cold-End" Errors

Use Chromel-Alumel *Extension Leads* with your Chromel-Alumel Thermocouples

Modern pyrometers, within themselves, leave little to be desired as far as accuracy of temperature measurement is concerned. They're precision built instruments . . . delicately balanced . . . equipped with automatic cold-end compensators . . . designed and engineered throughout to give you the fine degree of accuracy you need. And, on 3 out of every 4 heat treating installations, these accurate meters are calibrated for CHROMEL-ALUMEL thermocouples . . . durable, dependable, sensitive couples unconditionally guaranteed to register true temperature—E.M.F. values within extremely close specified limits.

Yet, in spite of all the fine accuracy built into these meters and couples, uncontrollable "cold-end" errors will frequently occur when so-called "compensating" lead wires are used. Here's why . . .

As you know, when wires of different composition are joined together, they form a thermo-electric junction. In the case of "compensating" leads connected to your Chromel-Alumel couples, these junctions are located just outside the furnace and unprotected from heat. Now, as these terminals get hot . . . *and they often get very hot* . . . or when one junction gets hotter than the other, the opposing E.M.F.'s they generate tend to become more and more unequal. And this variable inequality is inevitably reflected by serious plus or minus errors registered by your meter.

How to eliminate this common cause of "cold-end" errors? Simple! Use CHROMEL-ALUMEL EXTENSION LEADS with your CHROMEL-ALUMEL thermocouples. For only by using these wires of identical composition can you be sure of getting the full benefits of accuracy offered by today's improved pyrometers. Our Catalog 59-R tells the complete technical story . . . want a copy?

CHROMEL-ALUMEL couples and leads are available through your instrument manufacturer or pyrometer service company . . . ask for them by name!

HOSKINS MANUFACTURING COMPANY

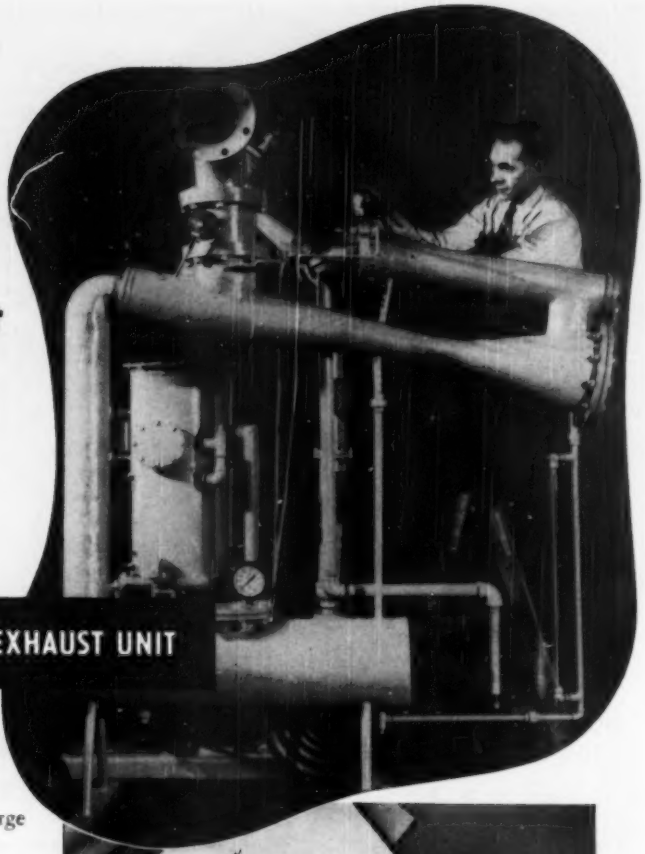
4445 LAWTON AVE. • DETROIT 8, MICHIGAN

NEW YORK • CLEVELAND • CHICAGO

West Coast Representatives in Seattle, San Francisco, Los Angeles
In Canada: Walker Metal Products, Ltd., Walkerville, Ontario

**the ... nickel-chromium resistance alloy that first made electrical heating practical*

Another DPi High Vacuum "Packaged" Unit that cuts pumping costs

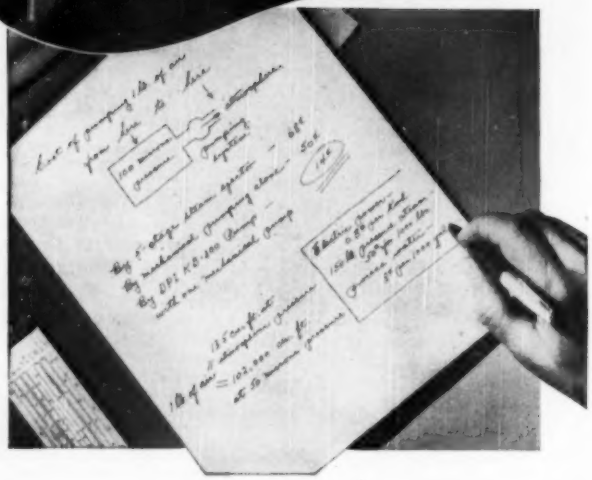


...THE NEW KB-300 EXHAUST UNIT

SPECIFICALLY designed to handle large volumes of gas, this unit provides:

- **High pumping speed in the pressure range from 50 to 500 microns.**
- **High allowable forepressure ranging from one to three millimeters Hg.**
- **High gas-handling capacity at low cost (see figures at right).**
- **Construction designed to handle water vapor and corrosive materials.**

For full information, write Vacuum Equipment Department, ***Distillation Products Industries,*** 753 Ridge Road West, Rochester 3, N.Y. (Division of Eastman Kodak Company).



DPi

high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3300 Eastman Organic Chemicals for science and industry.

COST WHEN MADE FROM FORGINGS—$1.714

Cost of forging per unit . . **$0.4228**

Production cost per unit (broached and then machined on chucking automatic) **$1.2912**

TOTAL COST PER UNIT—$1.714

COST WHEN MADE FROM TIMKEN TUBING—$1.47

Cost of tubing per unit . . **$0.293**

Production cost per unit (with mill-length tubing on 4-spindle 5" capacity automatic screw machine) **$1.177**

TOTAL COST PER UNIT—$1.47

Why this sleeve now costs 24.4¢ less

WHETHER you're making your hollow cylindrical parts from forgings or bar stock, chances are you can save money by switching to Timken® seamless tubing. For example, by using Timken tubing in place of forgings for the sleeve part shown here, the manufacturer cut his costs from $1.714 to $1.47 per piece.

This saving was possible for two reasons: 1. Unit for unit, Timken seamless tubing was far less expensive than forgings. 2. The mill lengths of tubing could be broached and machined on an automatic screw machine, whereas the forgings had to be broached and then maintained on a chucking automatic. The saving was so great that the cost of the new screw machine and tooling —$33,000—was more than paid for during the first year. The tables above give you the actual cost breakdowns.

Timken seamless tubing offers cost advantages over bar stock as well as forgings. The hole is already there. You can often start right in with finish boring. Scrap loss is reduced—machining time saved.

And you get better quality too. The piercing process by which Timken tubing is made is basically a forging operation, resulting in greater product strength. From tube to tube and heat to heat, this fine forged quality is always uniform, thanks to Timken's rigid controls.

OUR TUBE ENGINEERING SERVICE will choose the most economical size tube for you . . . guaranteed to clean up to your finish dimensions. Write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

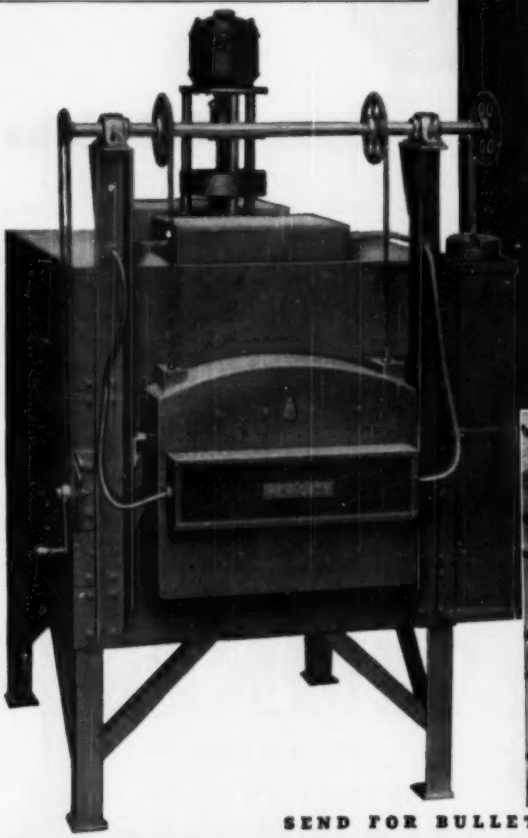
YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

The Chief Advantages OF THE HEVI DUTY Multi Range CONVECTION FURNACES Box Type

400° F TO 1850° F

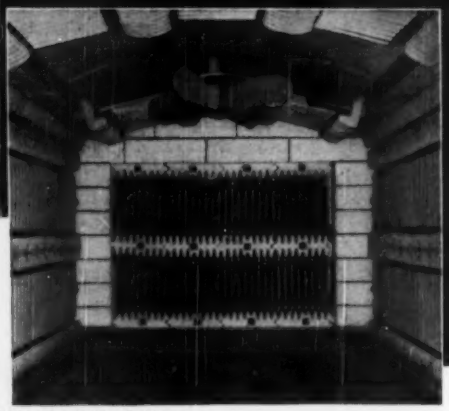
SEE US AT THE
METAL SHOW
BOOTH 1931



Are

- USE OVER A WIDE RANGE OF TEMPERATURES WITH
- HIGH DEGREE OF UNIFORMITY
- USE WITH OR WITHOUT FAN AGITATION
- WITH OR WITHOUT PROTECTIVE ATMOSPHERE
- PLAIN OR ROLLER RAIL HEARTH

Below: Interior view of a Multi Range Convection Furnace.



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HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES EXCLUSIVELY ELECTRIC

MILWAUKEE, WISCONSIN

Grinding Costs CAN Be Cut

NORTON "Know-How" Can Do It For You

1. RESEARCH

A staff of over 150 trained scientists and technicians constantly developing new abrasives and new bonds for lower grinding costs.

2. MANUFACTURING

The largest and most modern grinding wheel plant in the world with its thousands of skilled workers.

3. ENGINEERING

Abrasive engineers the country over —real experts who can come right into your plant and specify the most economical wheel for each of your grinding jobs.

NORTON ABRASIVES

Making better products to make other products better

Skillful Grinding Wheel Engineering . . . backed by PROGRESSIVE RESEARCH

ONLY the correct grinding wheel on each job can give you minimum grinding costs. And right near you there's a Norton abrasive engineer who can see that you get that correct wheel. He's an expert in wheel selection and he has the most complete variety of wheels in the industry to select from—including the exclusive 32 ALUNDUM abrasive. Back of him, continually developing still better abrasives and bonds to do your grinding jobs even more economically, are the largest and best-equipped research laboratories in the industry.

Adequate Grinding Wheel Stocks . . . . . STRATEGICALLY LOCATED

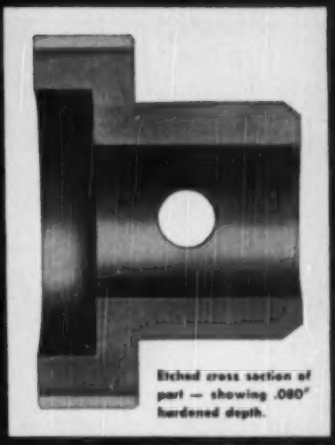
WHEN the correct wheels for your jobs have been determined, they are handy to you—on the shelves of Norton distributors in over 225 cities of the United States. And these local stocks are carefully selected to meet the particular needs of each individual area. Back of these distributor stocks are the Norton branch warehouses in five important industrial centers and the gigantic stock rooms at the mile-long Worcester plant. Serving foreign countries are six Norton branch grinding wheel plants and scores of distributors in all principal cities.

NORTON

ABRASIVES

Main Office and Plant of
NORTON COMPANY
Worcester 6, Massachusetts

COSTS CUT 94%



Etched cross section of part — showing .080" hardened depth.

with TOCCO* Induction Heating

A cost reduction of 94% resulted when heat-treatment of this Corn Harvester part was changed from carburizing to TOCCO-hardening. Look at the unit cost breakdown:

CARBURIZING		TOCCO-Hardening	
Degrease	$0.0020	*eliminated*	
Carburize	0.0200	*eliminated*	
1st quench	0.0150	TOCCO, heat and quench	$0.0060
2nd quench	0.0150	*eliminated*	
Draw	0.0050	*eliminated (self-draw)*	
Shotblast	0.0035	*eliminated*	
Internal Grind	0.0243	*eliminated*	
External Grind	0.0166	*eliminated*	
	$0.1014		$0.0060

"—Savings of 9½ cents per piece—$4770.00 on each 50,000 piece batch, *plus* an hourly production increase from 120 to 300 pieces per hour, *plus* improved quality of the product by virtue of the deeper case and stronger core."

Have you investigated TOCCO's cost-savings possibilities for your hardening, brazing, melting or forging operations? Why not write us today or send blueprints of your parts —no obligation, of course.

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

NEW **FREE** BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-10, Cleveland 1, Ohio

Please send copy of "A TOCCO Plant Survey—Your Profit Possibility for 1950".

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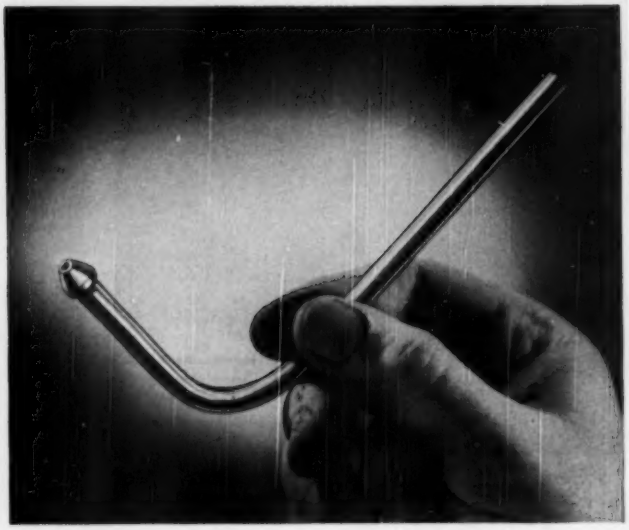
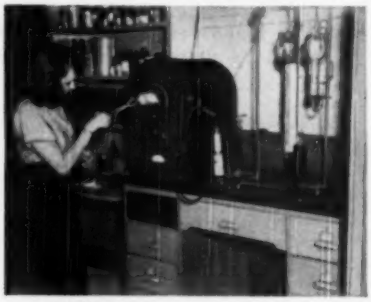
Fodder For 600 Horses Through This Small Tube



To guard against contamination by processing lubricants, the tubing is thoroughly degreased before each annealing operation.

Bright annealing and heat treating furnaces, with full instrumentation for control and record, assure uniform structure, a clean, smooth surface, and precise temper tolerances.



Routine tests are made to determine the carbon content of both raw material and finished tube.

● Only .061" I.D., the tube is the picture of power. It delivers fuel to a combustion chamber in a 600 horsepower diesel engine, under pressures as high as 9 thousand pounds per square inch. Annealed dead soft for easy upsetting and bending and to stand-up to vibration without cracking, cold drawn to a smooth finish, inside and out, dimensionally controlled to .002" it is a good example of tubing technology at work . . . an illustration of Superior's know-how in tubing production.

You may not be interested in whipping vibration, finding a tube which is easy to work, or controlling high pressures—but if anywhere in your product you use fine, small tubing in any practical metal or analysis, you will be interested in the Superior story about research, production, engineering, testing and close-as-your-phone distribution.

One of Superior's 55 distributors, with adequate stocks of standard analyses and sizes, is near you. For his name plus additional information about Superior tubing write today for Bulletin 31. Superior Tube Company, 2008 Germantown Avenue, Norristown, Pennsylvania.

Visit Superior Booth No. 2435, National Metal Congress & Exposition, International Amphitheatre, Chicago, Oct. 23-27.

ROUND & SHAPED TUBING

(.010" to ½" O.D. Max. Certain Analyses .035" max. wall to 1⅛" O.D.)

Available in:

Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, B-1095

Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100

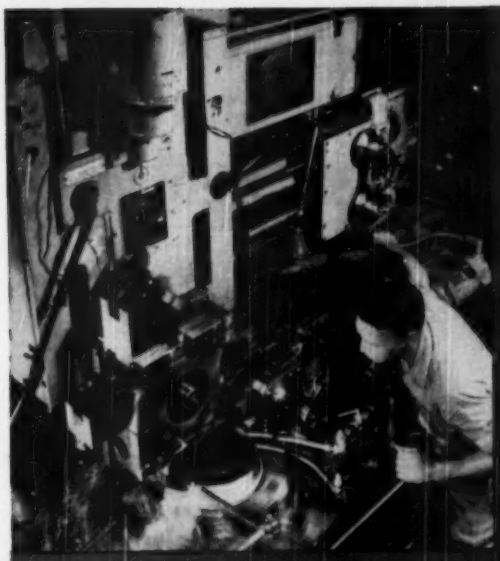
Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5

Nickel Alloys:
Nickel, "D Nickel", "L Nickel", "Monel", "K Monel", "Inconel", "Nichrome V", 30% Cupro Nickel, 18% Nickel Silver, Beryllium Copper.

Superior
THE BIG NAME IN SMALL TUBING

All analyses .010" to ½" O.D.
Certain analyses (.035" max. wall) Up to 1⅛" O.D.

*Reg. U. S. Trade Mark—Superior Tube Company • West Coast: PACIFIC TUBE COMPANY, 5710 Smithway St., Los Angeles 22, Calif. • ANgelus 2-2151



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Just how important cutting oils are"

reports a Midwest Machine Shop Superintendent.

"Sure, we knew different operations required different cutting oils. But it wasn't until we got into real trouble over rejects of one tricky part that we called in a Cities Service specialist.

That's when we learned about the complete line of oils available for specific applications. Now we don't set up a job without Cities Service expert advice on the right type of cutting fluid."

On all machining operations requiring cutting fluids, the correct tooling and the right type of cutting fluid will help give you these extra production benefits:

- ★ Longer Tool Life
- ★ Greater Accuracy
- ★ Better Finish
- ★ Higher Speed Operation
- ★ Closer Tolerance
- ★ Increased Production

A complete line of Petroleum Products for the Metal Working Industry including the following well-known brands: Chillo, Pacemaker, Q-T, Sentry, Optimus, etc.

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Please send me, without obligation, a copy of "Metal Cutting Fluids."

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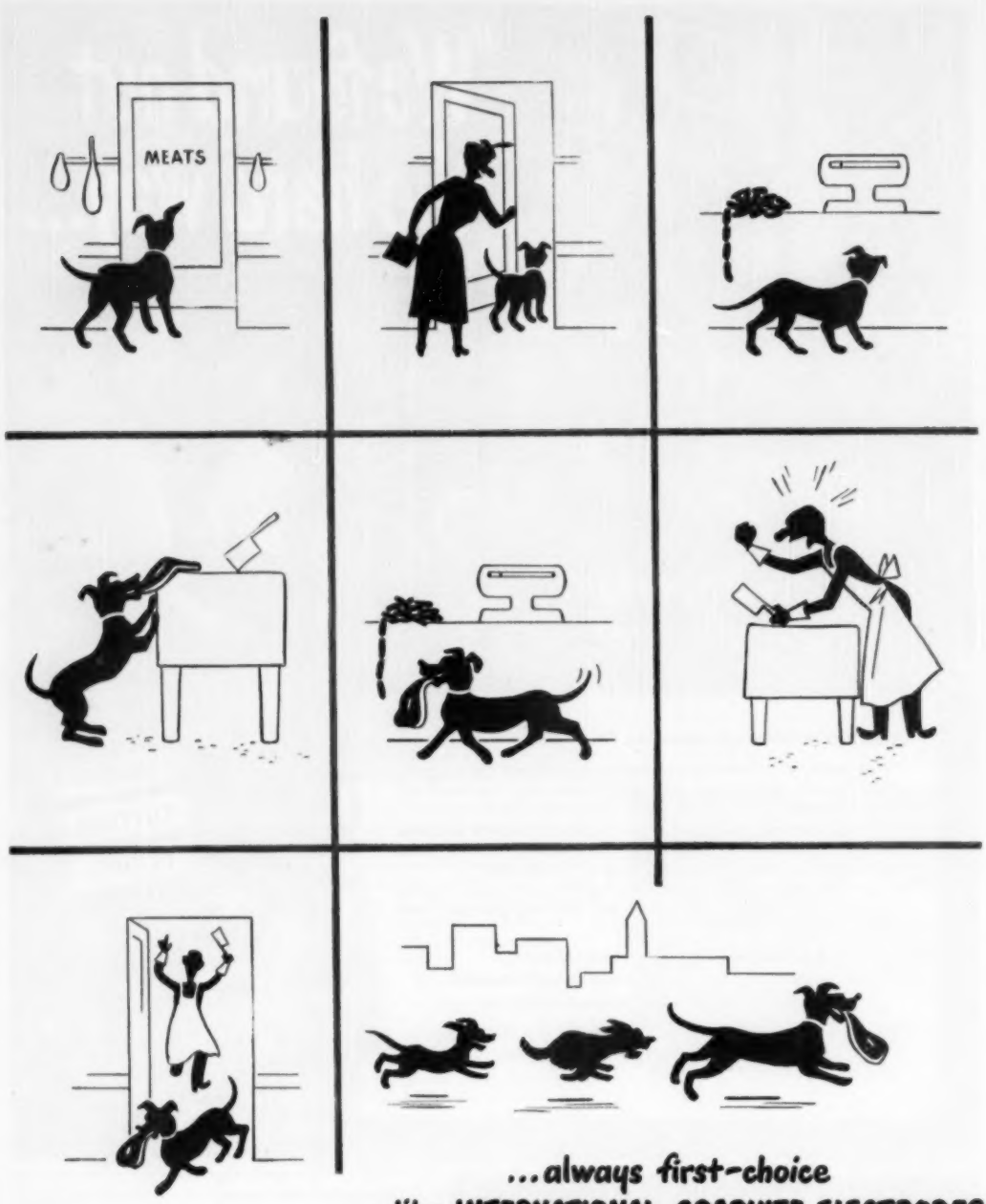

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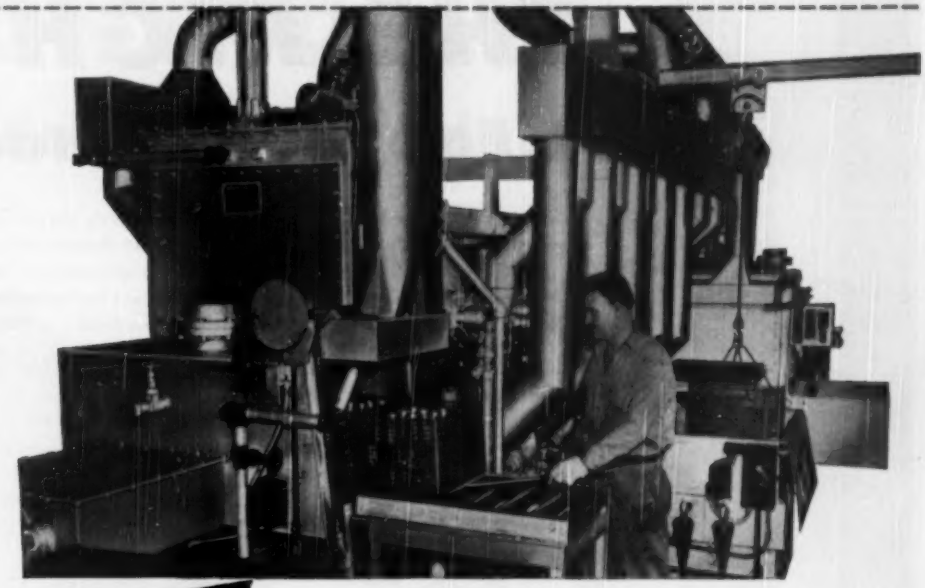
YOU CAN BE **SURE**.. IF IT'S

Westinghouse



FOR THE MAN WHO CAN'T BE SOLD

Here's the solution to your Gas Carburizing Problems

Westinghouse Therm-a-neering has the answers. This engineering and metallurgical service is offered with no obligation to the man who "can't be sold", but, who is willing to accept *proof* of efficiency and dependability. Therm-a-neering custom-builds equipment to fit your individual requirements, assuring smooth and economical operation of your heat-treating line.

Take the carburizing furnace shown above, for example: one continuous and complete operation puts all parts through the same cycle, same atmosphere, same temperature. Uniformity of parts is assured. Rejects are eliminated.

And the work is done fast. No handling of parts is required between charging and discharging. Doors open automatically. One operator handles all work easily. Production is maintained at 800 net pounds per hour.

This installation is typical of the way Westinghouse furnaces—both gas-fired and electric—are answering today's production problems. And because Westinghouse engineers have no favorite to play, they can study your problems from an unbiased point of view in helping you select the equipment to do your job most efficiently and economically.

Let Therm-a-neering help you. Call your nearby Westinghouse representative for details, or write Westinghouse Electric Corporation, 181 Mercer St., Meadville, Pa. J-10350

Therm-a-neering. **A HEAT AND METALLURGICAL SERVICE THAT OFFERS WITHOUT OBLIGATION:**

ENGINEERS—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

RESEARCH—A well-equipped metallurgical laboratory in which to run test samples to demonstrate the finish, hardness and metallurgical results that can be expected on a production basis.

PRODUCTION—A modern plant devoted entirely to industrial heating.

EXPERIENCE—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

Westinghouse

GAS AND ELECTRIC

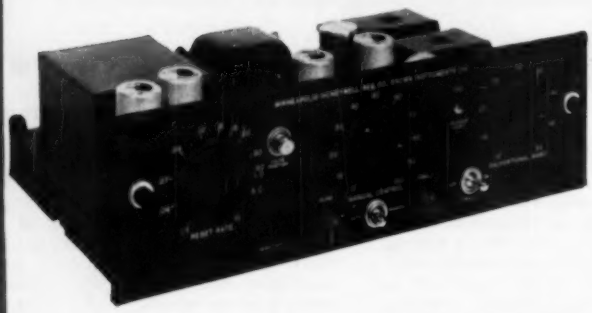
Furnaces

THE RIGHT

...For Your Furnace

No one controller can properly regulate *all* furnaces or correctly govern the heat treatment for *all* products. The *right* control must be determined by the *type of furnace and the size, shape and metallurgical requirements of the product.* In the complete Brown line there is a control form best suited to *your* furnace and *your* product . . . function-fitted to your needs.

Newest additions to the Brown line are the *Electr-O-Line* and *Electr-O-Pulse* proportional control relays. For detailed information, as well as for a discussion of function-fitted control for all of your heat-processing requirements, call in your local Honeywell engineer . . . he is as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.



FEATURING THE NEW

Electr-O-Line and Electr-O-Pulse

PROPORTIONAL CONTROL RELAYS

- The *Electr-O-Line* delivers a steady, modulated heat input.
- The *Electr-O-Pulse* delivers a time-modulated heat input.

CONTROLLER

...For Your Product

ON
DISPLAY AND
DEMONSTRATED
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1802

All Brown electric control forms take full advantage of the extreme sensitivity and rapid response of the famous *ElectroniK* Potentiometer . . . circular scale, circular chart and strip chart. You can see them all . . . plus the *Pyr-O-Vane* millivoltmeter controller and the *Protect-O-Vane* excess temperature cutoff . . . at the National Metal Exposition.

MINNEAPOLIS
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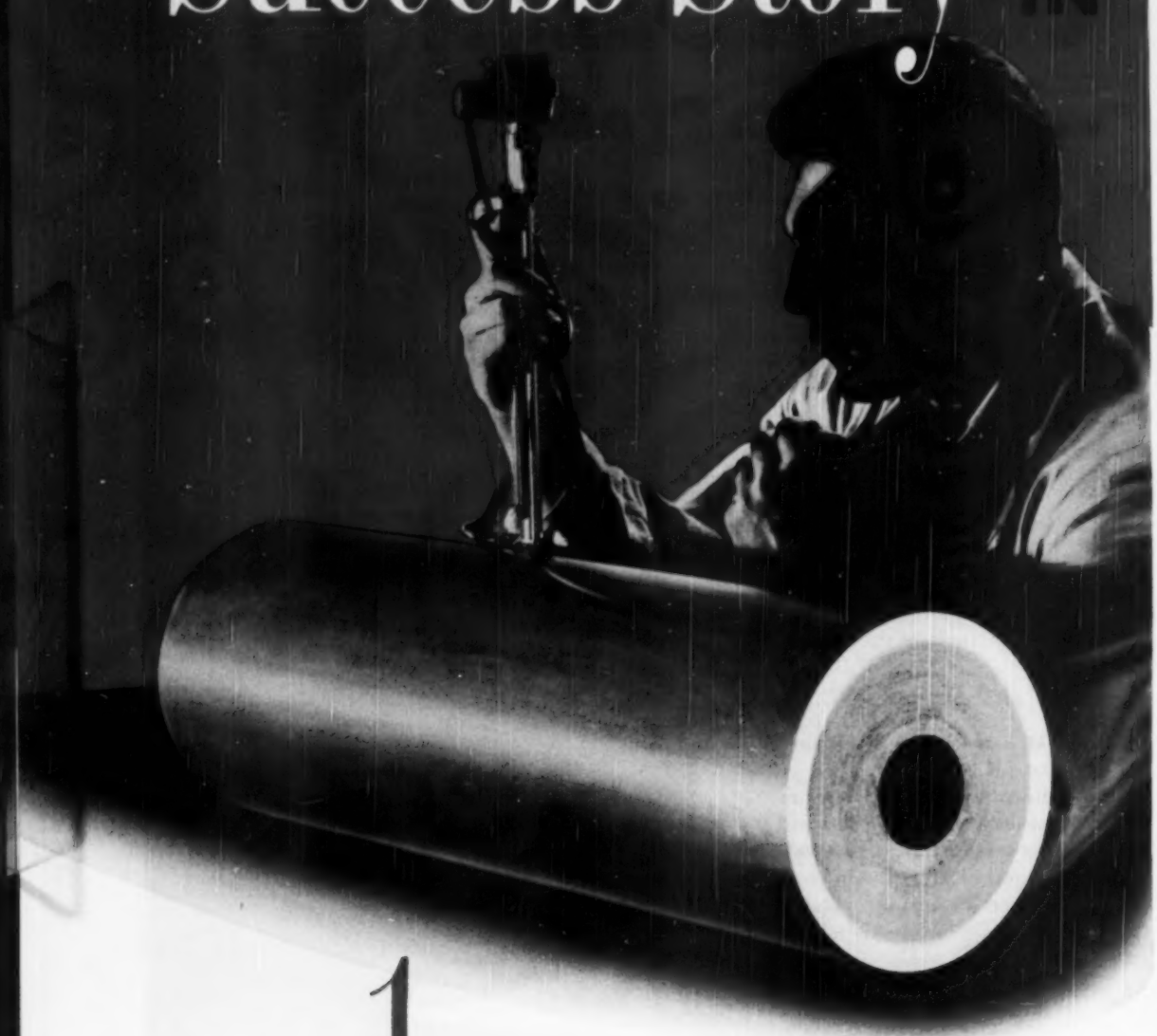
BROWN INSTRUMENTS

Success Story IN



1

GOOD BEGINNING—The heart of any milling operation is the grinding roll. The surface of the roll must be true and uniformly hard. Any deviation in hardness in the casting can lead to serious trouble—irregular corrugations that cause poor milling and an accelerated rate of wear. The necessity for uniform hardness to a pre-designed depth places a heavy burden of responsibility on the roll manufacturer, but "Dual Metal" measures up to every metallurgical "must."

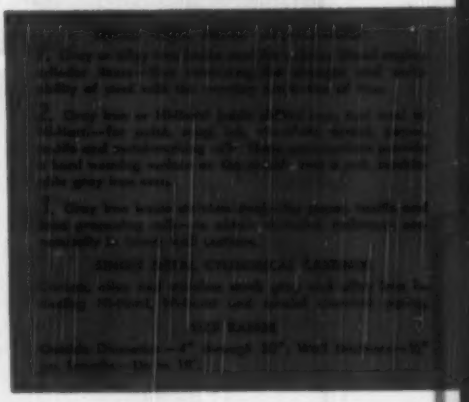
3 SHORT INSTALLMENTS

How "Dual Metal" Made a Better Flour Mill Roll

Four years ago, Allis-Chalmers, one of the leading manufacturers of milling machinery asked us to develop a centrifugally cast flour mill roll . . . a more efficient roll that would lower maintenance costs, provide for better control of the grinding operation, permit increased production. Working with Allis-Chalmers engineers, centrifugally cast dual metal grinding rolls were developed and put into production.

This is one of many diverse applications for dual metal centrifugally cast products serving a wide cross-section of industry.

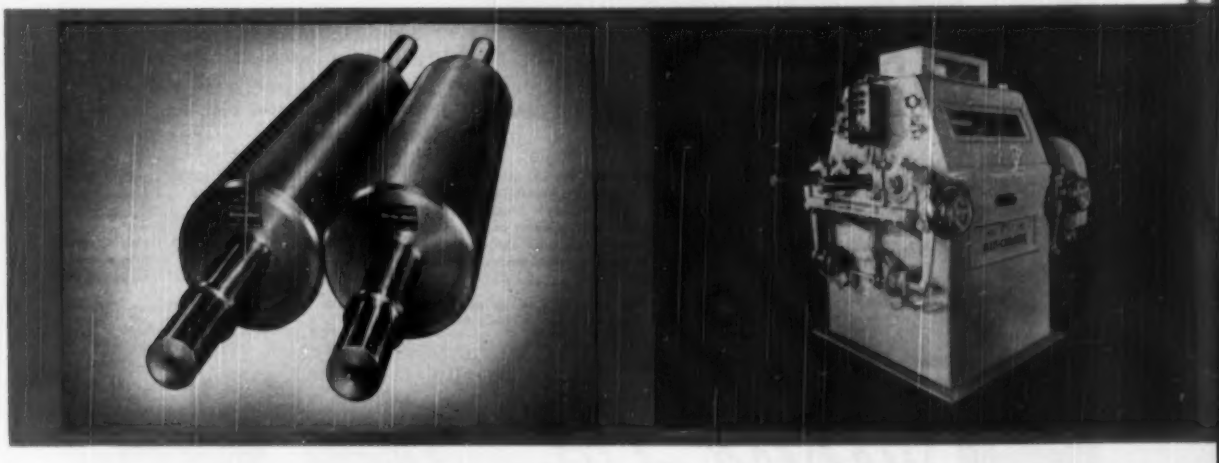
Certainly dual metal centrifugal casting, like any other process development, is not an industrial panacea. Nevertheless, this process has economic and mechanical advantages challenging the attention of the design engineer. Many cylindrically shaped products can be made, which combine into one integral structure, properties that no single metal can offer. This Allis-Chalmers' application may suggest ways in which you can profitably apply "Dual Metal". Our engineers will be glad to consider your individual problems.



U. S. PIPE AND FOUNDRY CO.

SPECIAL PRODUCTS DIVISION, BURLINGTON, NEW JERSEY

AMERICA'S LARGEST PRODUCER OF CENTRIFUGALLY CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

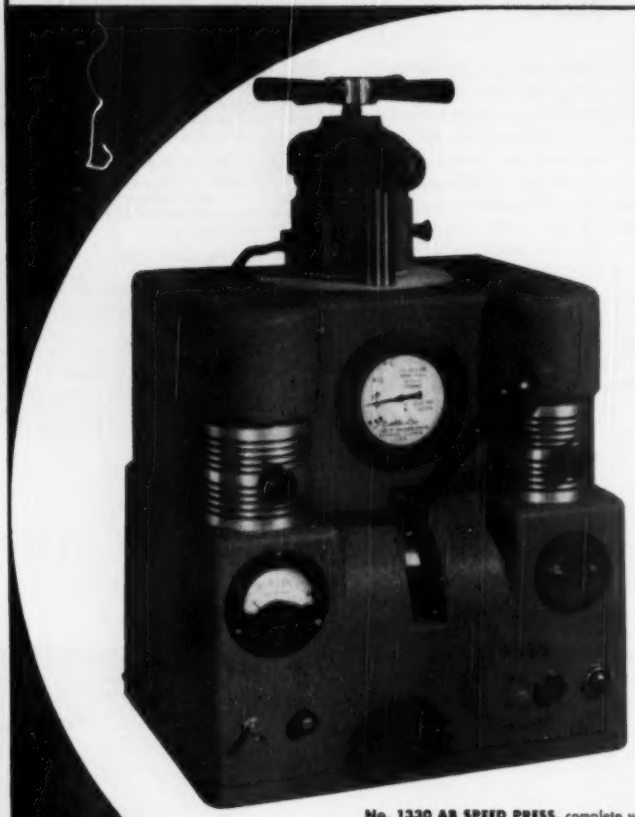


2 **BETTER END PRODUCT**—These "Circle-Chill"* rolls, as Allis-Chalmers identifies them after finishing, consist of a hard chilled iron outer shell of iron carbide and pearlite *metallurgically bonded* to a gray iron core. The iron carbide resists wear, the pearlite strengthens the structure, forming a matrix for the iron carbide. The soft iron core facilitates machining and fabricating. The complete bond between the chilled and gray iron, a characteristic of dual metal centrifugal casting, is effected by close control of metal temperatures and timing during casting.

3 **BEST RESULTS IN SERVICE**—Allis-Chalmers' specifications require semi-finished rolls of consistent and controlled chill depth, uniform hardness (in both the chilled iron outer shell and the soft gray iron core)—qualities that insure easy and satisfactory corrugating and long trouble-free service. Allis-Chalmers finishes these rolls with meticulous precision for the efficient, economical flour mills shown above. One more proof that cooperation in industry pays . . . and that two companies each contributing its specialty usually can produce a superior product.

*An Allis-Chalmers Trademark

Announcing THE NEW AB SPEED PRESS



This Streamlined AB SPEED PRESS

offers the metallurgist a new tool with the unparalleled qualities of precision workmanship, speed and convenience in the preparation of metallurgical specimens into plastic mounts.

The new AB SPEED PRESS produces perfect Bakelite mounts in 2½ to 3½ minutes and may be used with 1", 1¼" or 1½" molds.

Our introduction of preheated Premolds has revolutionized the preparation of metallurgical specimens.

The Premolds are dust-free, increase the convenience in handling, and are available at little extra cost. The Preheat Compartment reduces the curing time of thermoset molds to one-third of the time. The operation is controlled by Pyrometer, Timer and Thermostats.

These features in the new AB SPEED PRESS are destined to set a new mark in the development of metallurgical specimen preparation. It provides all metallurgists with the most advanced press equipment for speed, convenience, and economy never known before.

No. 1330 AB SPEED PRESS, complete with 1" mold assembly, thermostat controlled heater for 110 volts A.C., 600-watt, cooler blocks; 10,000-lb. capacity hydraulic jack; pressure gauge, pyrometer, timer clock, and pilot lights; premold assembly with heating compartment and ejector levers. With directions. **$380.00**

No. 1330-2 AB SPEED PRESS complete, same as No. 1330, except for 1¼" mountings. With directions. **$400.00**

No. 1330-3 AB SPEED PRESS complete, same as No. 1330, except for 1½" mountings. With directions. **$430.00**

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

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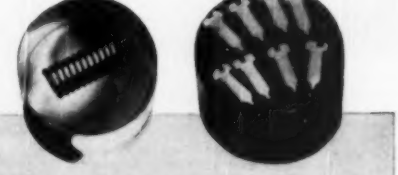


LEHIGH H

HIGH-CARBON, HIGH-CHROMIUM TOOL STEEL

For high-production dies

Photos Courtesy: Middlestadt Machine Co., Baltimore, Md.

Here's a tool steel that's engineered for high-production tools and dies. Experienced toolmakers call it the aristocrat among tool steels.

Quick Facts About LEHIGH H

Maximum Wear. Its high-carbon content makes it first choice wherever great resistance to wear is important. Use it for long runs.

Close Tolerances. Lehigh H is the ideal tool steel for maintaining split-hair accuracy. You can count on the very minimum change in size and shape during heat-treatment.

Safe Hardening. Lehigh H is cooled in still air from a hardening temperature of 1850 F. It eliminates cracking hazards for intricate dies, thin sections, short radii.

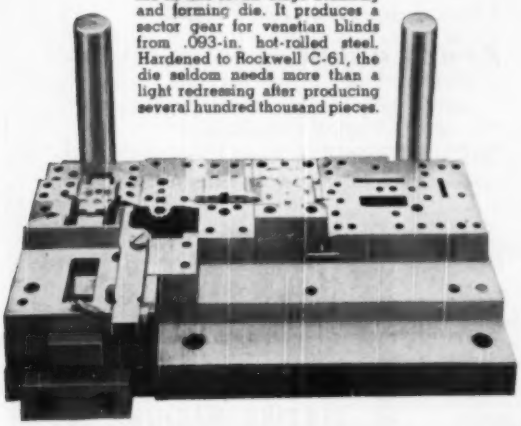
Heavy Duty. Lehigh H is extremely deep-hardening, even in large sections . . . and has high compressive strength for tools and dies subject to severe service.

Wide Application. Use it for tools and dies that blank, punch, form, draw, shear, and bend . . . for lamination dies, shear blades, wearing plates . . . master gages, bending rolls . . . and the like.

Typical Analysis:	C	Cr	V	Mo
	1.55	11.50	0.40	0.80

A trial in your own shop will convince you. Lehigh H is stocked by Bethlehem Tool Steel distributors in principal cities. The nearest Bethlehem sales office can give you full information.

Lehigh H is the key to long die life in this seven-stage blanking and forming die. It produces a sector gear for venetian blinds from .093-in. hot-rolled steel. Hardened to Rockwell C-61, the die seldom needs more than a light redressing after producing several hundred thousand pieces.



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On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation
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ULTRASONIC TESTED

Bethlehem Tool Steel

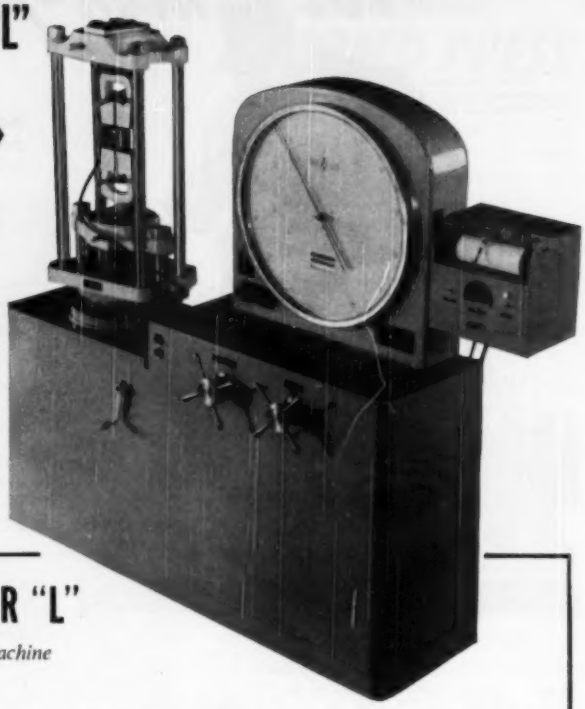
Get the Facts about...

The *NEW* OLSEN SUPER "L" TESTING MACHINE

the most versatile, low cost testing machine available today

Designed and Proved for Fast, Accurate and Convenient Operation on:

- ✱ Routine laboratory testing
- ✱ Specimens of fixed types and dimensions
- ✱ Quality and production control
- ✱ College and trade school instruction



Compare the OLSEN SUPER "L"

with any other type of Universal Testing Machine —Regardless of Cost.—

- ✱ Spread of testing ranges
- ✱ Ease of changing ranges
- ✱ Simplicity of inserting specimens
- ✱ Versatility of control
- ✱ Compact rugged construction
- ✱ Fool-proof indicating system
- ✱ Maintenance-free operation
- ✱ Dependable accuracy
- ✱ Low Cost

Learn about the Amazing Performance of the Olsen Super "L" with the NEW SelecTrange INDICATING SYSTEM with ATCOTRAN UNIT that makes possible a 50 to 1 spread of testing ranges on one 28" dial. Write today for Bulletin 40.

For the most recent advances in application of electronics to modern testing machines—VISIT OLSEN BOOTH #629 at the Metal Show, International Amphitheatre, Chicago, Ill., October 23-27, 1950. See this super machine in action!

TINIUS OLSEN

Testing & Balancing Machines

TINIUS OLSEN TESTING MACHINE CO.

2030 Easton Rd., Willow Grove, Pa.

In medieval times, a coat-of-arms had an importance that could not be overestimated. It was granted as a personal badge, signifying the attributes and accomplishments of its proprietor—and as such was respected thruout the civilized world. It had no duplicate.

In turn, the emblem imposed upon its owner a responsibility for maintaining an enviable reputation—a condition which stimulated general confidence in him.

Times have changed, but not all *things*. The sense of sanctity of an emblem is prevalent today as it was hundreds of years ago. That is why we take such pride in our trademark: NICHROME.

It is evidence of our accomplishment; our unique, personal badge — respected everywhere. Granted solely and wholly to us by the United States Patent Office over forty years ago, it symbolizes a series of superb electrical heat and corrosion-resistant alloys (developed and produced *only* by Driver-Harris Company) which today is serving industry all over the world.

Yes, there are other excellent heat and corrosion-resistant alloys, but *only one* NICHROME—the product of exclusive Driver-Harris knowledge and techniques.

We are well aware of our obligation to maintain its reputation, both here and abroad. In fact, such obligation is an inspiration to give of our best—now, tomorrow, and always.

FIFTIETH ANNIVERSARY
SPECIAL PURPOSE ALLOYS SINCE 1890
TRADE MARK REG. U.S. PAT. OFF.

Nichrome* is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco,
Manufactured and sold in Canada by
The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada

**T.M. Registered in United States Patent Office by Driver-Harris Company August, 1908*

UNIVERSAL-CYCLOPS STEEL CORP.

reports uniform cleaning of steel products with the

DU PONT SODIUM HYDRIDE DESCALING PROCESS

Stainless, high-speed, alloy and carbon steels handled with savings in time and materials.

In December 1945, the Universal-Cyclops Steel Corporation installed a Du Pont Sodium Hydride Descaling Bath in its plant at Bridgeville, Pennsylvania.

Designed to descale up to five tons per hour, the bath is used to clean quickly and uniformly Universal-Cyclops' production of stainless steel sheet, wire and strip; high-speed steel sheet and wire products; and alloy and carbon steel sheet, wire and strip. Installation of the Du Pont Sodium Hydride Descaling Process has resulted in savings in acid, metal, and operating time. In addition, the tendency of the sheet, wire and strip to "smut up" after acid treatment has been virtually eliminated.

Because of the excellent results obtained with the first unit, Universal-Cyclops installed a second bath in July 1946 to clean wire and rod in coils. Such "second installation" proof of satisfaction is common in plants operating Du Pont Sodium Hydride Descaling Baths.

Mail the coupon below. It will bring you a booklet describing the process and an offer of technical assistance in planning a unit for your plant.

Tune in Du Pont "Cavalcade of America" Tuesday nights—NBC coast to coast

DU PONT
Sodium hydride process for positive descaling

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.)
Electrochemicals Department
Wilmington 98, Delaware

Please send my copy of "Du Pont Sodium Hydride Descaling Process."

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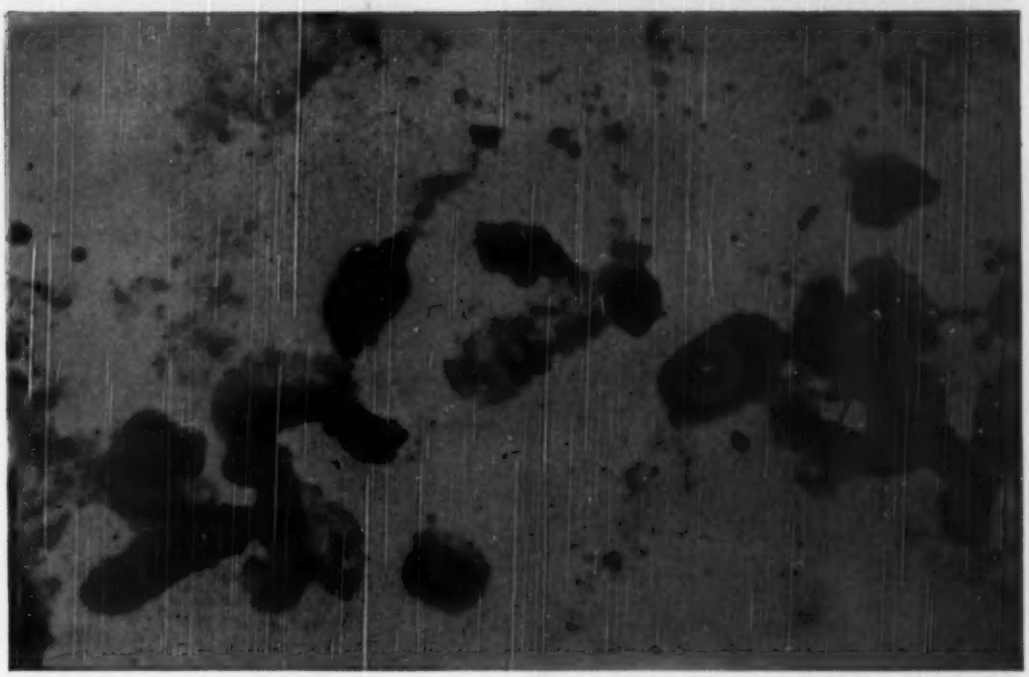
Firm _____

Position _____

Address _____



Bacteria Extracted from Soluble Oils Magnified 29,200X by Electron Microscope.

Deal a Blow to Bacteria!

Deal a blow to bacteria that attack lubricants and coolants causing them to go sour. The measures you take today to forestall the growth of these microorganisms may prevent the occurrence of machine down-time and wasted materials.

Dowicides, Dow's industrial germicides and fungicides, incorporated in cutting, grinding, rolling and hydraulic soluble oil emulsions will provide protection against the growth of bacteria. Thus the service life of the oil will be increased. Dowicides come in both oil and water-soluble types.

Investigate Dowicides today and do away with expensive production delays and costly material wastes caused by bacteria. Complete laboratory facilities are maintained by Dow to help you solve your problems. Contact your nearest sales office or write direct.

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Dow Chemical of Canada, Limited, Toronto, Canada

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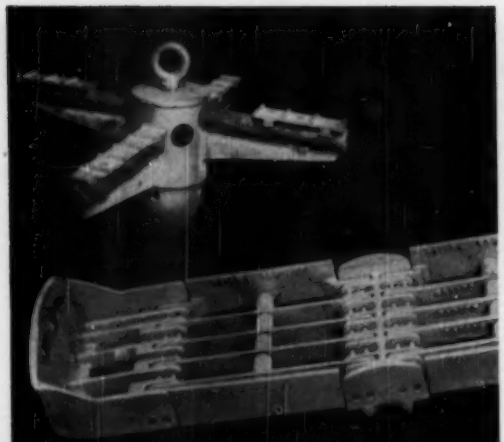


FAHRITE

HEAT AND CORROSION *Alloys*

in **HEAT-TREATING**

At temperatures where ordinary steel would disintegrate, Fahrite holds up. Fahrite heat-resistant alloy is now successfully serving in retorts, carburizing boxes, furnace hearths and many other severe applications. Our metallurgists will be glad to analyze your needs.

THE OHIO STEEL FOUNDRY COMPANY

SPRINGFIELD, OHIO

Plants at Lima and Springfield

No. 44—Product of Northern Electric Company Chicago 25, Illinois

This Northern Electric Blanket is "Just what the Doctor ordered" for restful slumber, undisturbed by temperature changes or cumbersome coverings. Actuated by Chace Thermostatic Bimetal, its Underwriters' approved thermostat maintains the warmth you want within one degree all through the night.

Pre-setting determines the travel of the bimetal actuating element, regulating time of the heating cycle. When the circuit is closed, current is supplied to the blanket heating element and to a heater coil mounted near low-expansive side of the bimetal. Thermal response of the contact-carrying bimetal pulls it away from a fixed contact, breaking the circuit. As the bimetal cools it returns toward closed position, where it enters the field of a permanent magnet which closes the circuit with a snap action to begin another heating cycle.

Chace Thermostatic Bimetal is available in strips, coils, random long lengths, completely fabricated elements or sub-assemblies ready for installation in your product. You'll find the Chace Application Engineer extremely helpful in design problems involving temperature-responsive devices. We invite you to take advantage of our consultation service.

W. M. CHACE CO.

Thermostatic Bimetal

1626 BEARD AVE., DETROIT 9, MICH.

METAL STRIPPER: Enthone, Inc., has announced the development of a new product for the rapid stripping of nickel, tin, lead and chromium from copper, brass and other copper alloys without attack upon the base metal. The process involves no current. The work to be stripped is immersed in an acid solution containing Metal Stripper N-165 and rapid removal of nickel and the other metals mentioned is accomplished. Stripping rates as high as 0.006 in. per hour of nickel have been obtained. The process is stated to be ideal for removal of nickel from bulk plated work as well as heavier plated objects, such as percolators, flashlights, plumbing goods and other items made of copper. It is also suitable for rapid removal of nickel and chromium from tips of plating racks, thus reducing over-all maintenance costs on plating racks.

For further information circle No. 776 on literature request card on p. 432B

BURNER: A new combination oil and gas burner for all furnaces requiring high temperatures and intense transfer of heat to materials has been announced by Bloom Engineering Company, Inc. Heat releases up to 750,000 Btu. per cu. ft. of combustion volume can be obtained with the high thermal release (HTR) burner, yet a turndown ratio of greater than 10 to 1 enables low input for holding purposes.

The HTR Burner is a nozzle mix burner, said to differ from conventional designs in that fuel and combustion air are pre-mixed within the alloy nozzle, forming a uniform, combustible mixture when discharged into the furnace. The nozzle, made of a heat-resistant alloy, reportedly is safe to operate even when subjected to a furnace temperature of 2800° F., and is designed to prevent the flame from traveling back, regardless of the rate of flow.

For further information circle No. 777 on literature request card on p. 432B

TEMPERATURE INDICATORS: TEMPIL° CORPORATION announces the development of additional high temperature ratings of TEMPILAQ° to indicate 1650, 1700, 1750, 1800, 1850, 1900 and 1950° F. Beginning with 113° F., TEMPILAQ° is now available in 12½-degree steps to 400° F. and in 50-degree steps from 400 to 1950° F.

TEMPILSTIKS°, the crayon form of temperature indicator, and TEMPIL° PELLETS are available in similar intervals from 113 to 2000° F. In addition, TEMPIL° PELLETS can be supplied in 50-degree steps in the range from 2000 to 2500° F.

For further information circle No. 778 on literature request card on p. 432B

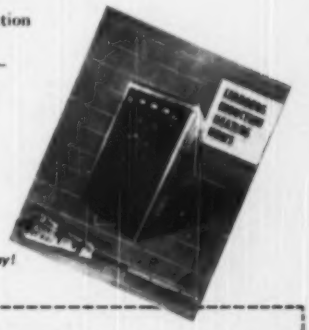
LINDBERG

INDUCTION HEATING UNITS

tough... rugged...

DESIGNED FOR CONTINUOUS OPERATION WITH A MINIMUM OF DOWNTIME!

Bulletin No. 1440, "Lindberg Induction Heating Units" gives complete details on 5, 10, and 25 KW Units—describes new and unique features—"Conditioned Cooling", "Checklite" preventative maintenance, oversized components, and many others.



Send for your copy of Bulletin No. 1440 today!

LINDBERG ENGINEERING COMPANY
2448 W. Hubbard Street, Chicago, Illinois

Please send me my copy of Bulletin No. 1440, "Lindberg Induction Heating Units", no obligation of course.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

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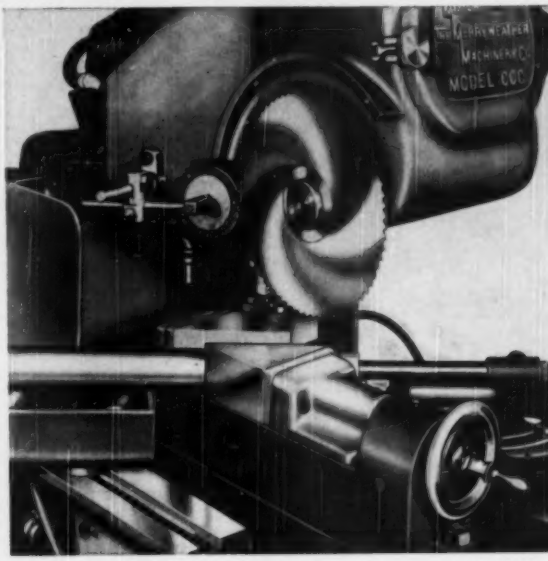
For further information circle No. 778 on literature request card on p. 432B



CIRCULAR SAWING MACHINE: Fast and accurate square or angular cutting off of ferrous or nonferrous materials up to 3 in. round or square is now possible on the new Model No. 00-G circular sawing machine, manufactured by the Motch & Merryweather Machinery Company. Angular cutting up to 45 degrees is made possible by inserting clamping jaws of the desired angle and moving the supporting stock conveyor. Where it is not convenient to move the stock conveyor, the Model No sawing machine can be swivel base, allowing be swiveled to the de gle. Stock can be fed i either manually or matically-operated, air feeder for standard le in. with additional le for special application **For further informatio on literature request**

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Clip this Chart for Reference

SPECIFICATION CHEMICALS FOR THE GOVERNMENT AND ITS CONTRACTORS

Phosphatizing, Rust Proofing and Paint Bonding Chemicals

SPECIFICATION NUMBER	ACP SPECIFICATION CHEMICAL
QQ-P-416	"Lithoform"
	"Zinodine"
RR-C-82	"Lithoform" No. 32
MIL-C-5541 (See also QPL-5541-1)	"Alodine"
MIL-S-5002	"Alodine"
	"Granodine" (Dip, Spray and Brush grades)
JAN-C-490, Grade I	"Granodine" (Dip, Spray and Brush grades)
JAN-F-495	"Granodine" (Dip, Spray and Brush grades)
	"Lithoform"
JAN-L-548	"Permadine"
AN-E-19	"Alodine"
	"Zinodine"
AN-F-20	"Alodine"
	"Granodine" (Dip, Spray and Brush grades)
	"Lithoform"
	"Permadine"
	"Thermoil-Granodine"
	"Zinodine"
	(See also U.S.A. 3-213)
U.S.A. 57-0-2	
Type II, Class A	"Thermoil-Granodine"
Type II, Class B	"Permadine"
Type II, Class C	"Granodine" (Dip, Spray and Brush grades)
U.S.A. 51-70-1	
Finish 22.02, Class A	"Thermoil-Granodine"
Finish 22.02, Class B	"Permadine"
Finish 22.02, Class C	"Granodine" (Dip, Spray and Brush grades)
U.S.A. 50-60-1	"Granodine" (Dip, Spray and Brush grades)
U.S. Navord O.S.675	"Alodine"
U.S.N. Appendix 6	"Lithoform"
Navy Aeronautical M-364	"Permadine"
	"Thermoil-Granodine"
AN-C-170	(See MIL-C-5541)
U.S.A. 72-53	(See AN-F-20)
AXS-1245	(See JAN-C-490)

Rust Removing and Metal Conditioning Chemicals

SPECIFICATION NUMBER	ACP SPECIFICATION CHEMICAL
JAN-C-490, Grade II	
Type 4	"Deoxidine" Nos. 126, 512, 526, 624, 670
Type 5	"Deoxidine" Nos. 170, 171, 670
U.S.A. 3-213	
Type I	"Deoxidine" (Wash-off grades)
Type II	"Deoxidine" (Wipe-off grades)

Metal Cleaning Chemicals

SPECIFICATION NUMBER	ACP SPECIFICATION CHEMICAL
JAN-C-490, Grade II	
Type 2	"Ridoline"
Type 6	"Ridosol"
U.S.A. 3-192	"Ridoline" No. 3192
U.S.N. Appendix 6	"Deoxidine"

Acid Inhibitors, Pickling

SPECIFICATION NUMBER	ACP SPECIFICATION CHEMICAL
U.S.N. 51-1-2	"Rodine"

Write us for descriptive folders and further information on the specification chemicals listed above. Additional copies of this chart are available on request.

Pioneering Research and Development Since 1914

AMERICAN CHEMICAL PAINT COMPANY

AMBLER, PA.

Manufacturers of Metallurgical, Agricultural and Pharmaceutical Chemicals

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

BRAZING: The trend in silver alloy brazing, where volume production is involved, is toward almost complete mechanization by means of heating equipment with indexing tables or conveyor lines, by parts positioning through jigging arrangements and by preplacing the silver brazing alloy in wire ring or other prefabricated form. In the example shown here, stamped steel "roll backs" for door locks are fluxed and assembled by the operator with a tiny square of Easy-Flo placed between the teeth of the roll backs. After placing three assemblies in each jig, the machine takes over. First, an air cylinder plunger shoots forward, clamping the assemblies in the jig. A movable induction heating coil then drops automatically into position for a 9-second application of heat. The coil goes up and the assemblies ride two stations while the brazing alloy sets. Finally, a second air cylinder plunger ejects the finished assemblies from the indexing table into a shipping crate. With this mechanical set-up a saving of one third was lopped off the cost of producing 500,000 roll backs. Production can be doubled by adding a second heating station and another operator to the present indexing table. Handy & Harman.

For further information circle No. 780 on literature request card on p. 432B

ZINC PLATE: A brilliant, corrosion-resistant finish on zinc plate for ⅛ of a cent per square foot is the claim of the Chemical Corporation for its new Luster-On Utility-15 Zinc Bright Dip. This new dip may be diluted up to ten times without loss of brilliance or corrosion-resistance. The solution is 95% inorganic materials and hence very stable. Great uniformity of results and freedom from iridescence are also claimed.

For further information circle No. 781 on literature request card on p. 432B

BRAZING ALLOY: Nicrobraz is a heat- and corrosion-resistant alloy for brazing stainless steels. This new material is a stainless type. The joint of a stainless steel assembly brazed with Nicrobraz has equal strength at 2000° F. plus better corrosion and oxidation resistance than parent metal.

Nicrobraz can be used to braze 300 and 400 series stainless steel, Inconel, S-590, Monel, alloy steels, tool steels, carbon steels, and special stainless steels. An assembly to be brazed with Nicrobraz is prepared the same as for copper brazing. It has been found that the joint clearance should not be over 0.002 in. where highest quality joints are desired. As stainless steels

oxidize in regular brazing furnace atmospheres, brazing is best accomplished in pure, dry hydrogen of −40° F. dew point or below. Nicrobraz is applied to the part and is held in place with Nicrobraz cement; it will flow throughout a joint by capillary action when heated to 2050° F.

Complete tests show that a Nicrobraz joint has a much higher remelting point (2600° F.) than the original Nicrobraz melting point (about 1850° F.). The tensile strength of a butt brazed super alloy specimen is 120,000 psi. at room temperature which is about 90% that of parent metal strength; at 2000° F. the tensile strength is 99.8% that of the parent metal. Of all the brazing materials tested, the next best possesses only 35% the tensile of the parent metal at 1600° F. Wall Colmonoy Corp.

For further information circle No. 782 on literature request card on p. 432B

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METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

Oct. 1950

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Name _____ Title _____

Company _____

Products Manufactured _____

Address _____

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Postcard must be mailed prior to December 1, 1950—
Students should write direct to manufacturers.

ROLOCK

FABRICATED ALLOYS

Visit us at Booth No. 532, Metal Show, Chicago, week of October 23rd.

Photograph shows fire-flash at instant basket and load contacted the quench.

. . . just about the toughest shock for *any* basket. But Rolock fabricated-welded Pit Type Furnace Baskets now standardized at the Peck, Stow & Wilcox plant, Southington, Conn., are showing fine performance records in gas carburizing.

Their department head says, "Very satisfactory, not only in view of severe conditions, but also because they eliminate rough work handling from furnace to quench, which previously caused excessive distortion."

DETAILS: Baskets Inconel frame and cloth, 20" dia. x 11"; weight 45 lbs.; load 225 lbs. (hand tool parts); furnace temperature 1650° F.; oil quench (100° F.); ratio live-dead load 5 to 1; basket life 2 years. Furnace load 3 baskets.

ADVANTAGES: Light weight, greater furnace capacity, easier handling, uniform quench (wire cloth sides) providing complete case depth uniformity, minimum dragout loss of quench medium, lower costs.

Rolock engineers are cutting heat-hour costs and improving product quality. May we do so for you? Write for catalog.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • HOUSTON • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES • MINNEAPOLIS

ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

6-RL-50

CUT FURNACE TIME and FUEL BILLS with "PSC" LIGHT-WALL RADIANT TUBES

As a leading supplier of tubing to builders and users of radiant tube furnaces, Pressed Steel Company's assemblies dependably furnish such general features as compactness, removability, uniform heating over tube length, etc. The distinctive feature of PSC radiant furnace tubes is their light-wall construction. Installation records repeatedly show that this feature effects marked economies in fuel and furnace time. Our "light-wall" construction is based on a quarter century's experience in precision fabrication of sheet alloys.

TUBE ASSEMBLIES FOR EVERY PURPOSE

Tubes for all types of radiant furnaces. We specialize in secondary burner tubes for highest temperatures. Let us show you how PSC light-wall tubes cut maintenance and furnace time.

PSC EQUIPMENT IS "ALLOY RIGHT"

Light-Weight **Heat-Treating Equipment for Every Purpose**

Carburizing and Annealing Boxes · Baskets · Trays · Fixtures · Muffles · Retorts · Racks · Annealing Covers and Tubes · Pickling Equipment · Tumbling Barrels · Tanks · Cyanide and Lead Pots · Thermocouple Protection Tubes · Radiant Furnace Tubes and Parts · Heat, Corrosion Resistant Tubing

We precision assemble the most complicated designs of radiant furnace tubes. Send blue prints or write us to your needs. We fabricate heat-treat units from the complete list of alloys. You can choose the metal that is "alloy-right" for your needs.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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"We get longer tool life, better finishes with GULF LASUPAR CUTTING OIL

"We've found Gulf Lasupar Cutting Oil—blended with Gulf Cut-Aid—the practical answer to our reaming problems," says this machine shop Superintendent. "On these cast iron cylinders, for example, we're getting better finishes than with the oil we used previously, and rejects are negligible. And we've been able to increase tool life substantially. The reamers for this job have been used constantly for seven eight-hour shifts and are still in perfect condition."

These are typical of the results obtained with this effective combination in scores of progressive machine shops. Gulf Lasupar Cutting Oil is specially compounded to make it exceptionally active over the entire range of a cutting operation. Gulf Cut-Aid gives improved flushing action, adds to cooling properties, and helps increase penetration and wettability.

Let a Gulf Lubrication Engineer show you how Gulf Lasupar Cutting Oil and Gulf Cut-Aid can help you increase tool life and improve finishes. Write, wire, or phone today.

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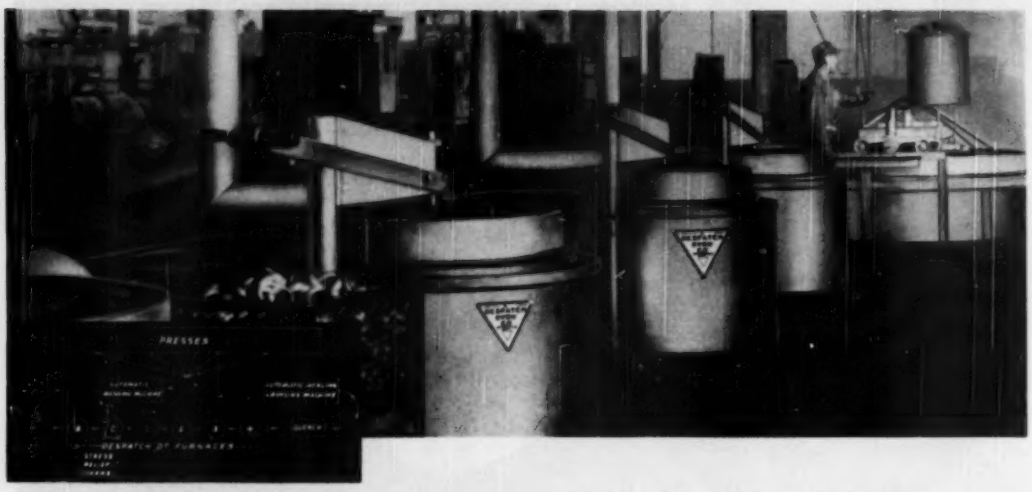
DESPATCH FURNACES

for ANNEALING BRASS SHELL CASES



This DESPATCH layout produces 4800-20mm. shell cases per hour

This compact and efficient layout requires a small investment, and a minimum of floor space. A comparatively small crew can control the heat treatment of 4800—20mm. shell cases per hour.

FEATURES SMOOTH OPERATION—

Blanks are brought from the presses to automatic washing machines, then are dumped into furnace baskets and carried by monorail to where they are placed into the loading chamber of the DESPATCH furnace for heat treatment. Monorail system then carries the blanks to the quench tank and from there into a machine that automatically pickles, rinses and neutralizes them. After further machining operations the final stress relief is carried on in a batch type, truck loaded DESPATCH furnace. This is one of many plant layouts in our files for heat treating production of shell cases.

Guaranteed Performance with DESPATCH "Gas Fired" FURNACES

Be prepared for increased production capacity with absolute assurance of proper annealing with uniform grain size in every load. DESPATCH furnaces are specially designed to give you faster heat transfer and uniform heat control to every part of the work chamber.

WRITE, PHONE, WIRE TODAY!

Blue prints for the layouts of 20mm.—37mm.—40mm. and larger shell cases are available upon request. Layouts for heat treating projectiles also available. We assure you prompt delivery of any furnace you need in a hurry. Write, phone or wire for blue prints and quotations today.

MINNEAPOLIS OFFICE:
619 S. E. Eighth Street

CHICAGO OFFICE:
7070 N. Clark Street

DESPATCH OVEN COMPANY

An example of the HIGH FATIGUE LIFE you can get in SANDVIK SPRING STEEL

Compressor valves are one of the uses of Sandvik steel demanding extra high fatigue life. In the performance of their extremely vital job in the heart of a compressor, these valves vibrate many, many times per second. The fact that they are required to give years of trouble-free service is evidence of the fatigue resistance you'll find in Sandvik steels.

DO YOU HAVE YOUR COPY OF THIS FREE, NEW SANDVIK CATALOG?
Catalogues 785 sizes. Gives thickness, width, hardness, types of edges and weight in pounds per hundred feet. Also useful conversion tables. Write, on your letterhead, today.

When you need a spring steel that won't "tire" easily remember Sandvik.

This high fatigue life available in Sandvik steels is a result of the basic purity of raw materials used and close controls maintained throughout all processing.

Sandvik strip steels are available:

- **In straight carbon and alloy grades**
- **In special analyses for specific applications**
- **Annealed, unannealed or hardened and tempered**
- ***In thicknesses from .001"***
- **In a wide range of widths**
- **Unpolished or polished bright, yellow or blue**
- **With round or square edges**

Phone, write or wire your nearest Sandvik office for further information or technical help.

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SANDVIK CANADIAN LTD., 426 McGill St., Montreal, Canada

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SOME SANDVIK SPECIALTY STRIP STEELS · Steel for Textile Machine Parts · Band Saw Steels; Metal Band, Wood Band and Spring Temper · Camera Shutter Steel · Clock and Watch Spring Steels · Compressor Valve Steel · Doctor Blade Steel · Feeler Gauge Steel · Knife Steels · Razor Blade Steel · Reed Steel · Shock Absorber Steel · Sinker Steel · Spring Steels · Trowel Steel · Vibrator Reed Steel, etc.

Now You Can Get **GAS FREE HIGH PURITY METALS** in ingot form

Typical Analysis
10 Pound
Iron Ingot

Nitrogen	< 0.001%
Hydrogen	<0.0001%
Oxygen	< 0.02%
Aluminum	< 0.001%
Carbon	< 0.005%
Chromium	< 0.001%
Columbium	< 0.001%
Copper	< 0.001%
Manganese	< 0.001%
Molybdenum	< 0.001%
Nickel	< 0.001%
Phosphorous	< 0.005%
Silicon	< 0.01%
Sulphur	< 0.005%
Tin	< 0.001%
Titanium	< 0.001%
Tungsten	< 0.001%

ORDINARY IRON
Note the heavy distribution of oxide inclusions resulting from oxygen content of 0.1 . Magnification 500 X

GAS FREE HIGH PURITY IRON
Note the minute oxide inclusions resulting from vacuum processing to obtain an oxygen content of 0.02 . Magnification 500 X

National Research Corporation, as a result of years of experience in the operation of metallurgical processes at pressures of 0.001 millimeters of mercury and less, is now supplying Gas Free High Purity Metals which have been melted and cast under the most perfect conditions for exclusion of occluded gases, accurate control of composition, and maintenance of uniform properties.

For the research laboratory requiring metals of the highest purity with minimum gas content, National Research Corporation will supply Gas Free High Purity Iron in 10 pound ingots from stock. Other metals including copper, cobalt, and nickel are similarly available. Special alloys, held to extremely close composition tolerances, may be produced on order.

Ingots up to 200 pounds will be supplied to users who desire to carry out larger experimental operations or production runs requiring materials of the highest quality. Arrangements can be made to supply Gas Free High Purity Metals in sheet, strip, and wire form.

Write for further particulars on specifications, prices, and delivery schedules.

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Even if the plating wears off, tableware keeps its beauty—when it's fashioned of Riverside *Nickel Silver*.

This tough, close-grain metal is *silvery white clear through*, shows no ugly patches when the surface plating goes. And that happens less frequently because Riverside *Nickel Silver* permits a smooth, uniform plate without preplating or flash coating.

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FREE—*Send for this Pocket-size Alloy Handbook and Guide to Specification.*

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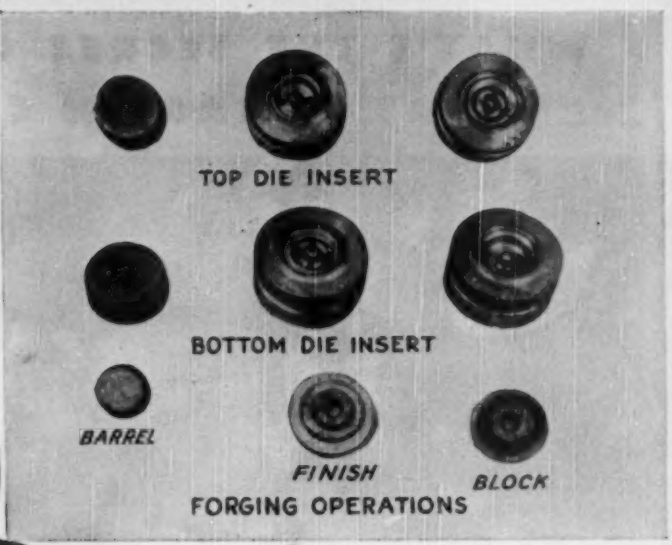
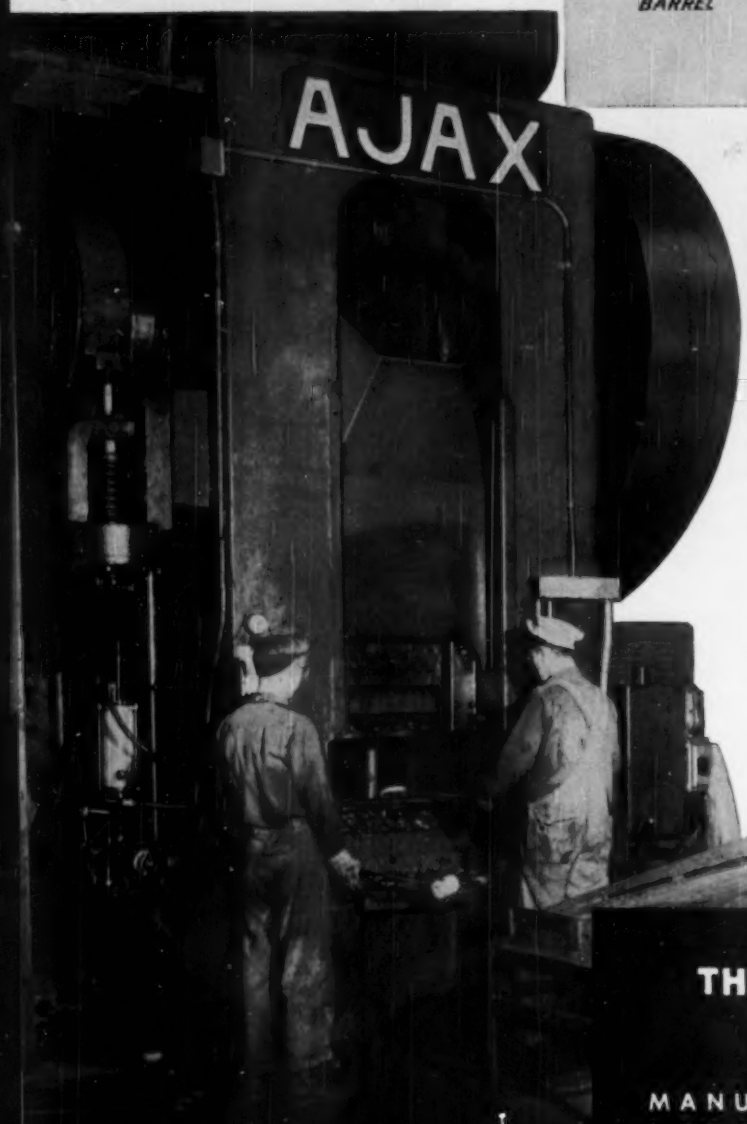


Dies and Forging Operation for Tractor Gear Blank



Forging Tractor Part on AJAX FORGING PRESS at International Harvester Company, Louisville, Kentucky, Works.

The need of high production efficiency in competitive industry today emphasizes the importance of the economies gained through Press Forging of Gear Blanks, as well as many other types of multi-stage forgings. The forgings are better because they have a high degree of uniformity of size and added strength due to the hot forging process shaping the grain flow so that the finished gear has a stronger structure. Forging is faster, as the quick air clutch controlled press ram achieves so much from a single stroke. And press forging is cheaper through saving in manpower both in forging and in subsequent finishing operations. There is still further saving in metal due to a minimum of flash and in minimum die replacement cost.

Write for Bulletin 75-B

THE Ajax

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SO will effectively loosen the most stubborn, heavy, impacted, ground-in buffing compounds for subsequent removal in the electrolytic tanks. The latest developments in metal cleaning research have been incorporated in this new product. Its superior penetrating and wetting action quickly loosens dirt and impacted buffing compounds from *any metal.* SO can be used in still tank, fully and semi-automatic machines and is compatible with a wide range of temperatures. Because SO produces stable emulsions at low concentrations, it assures thorough rinsing.

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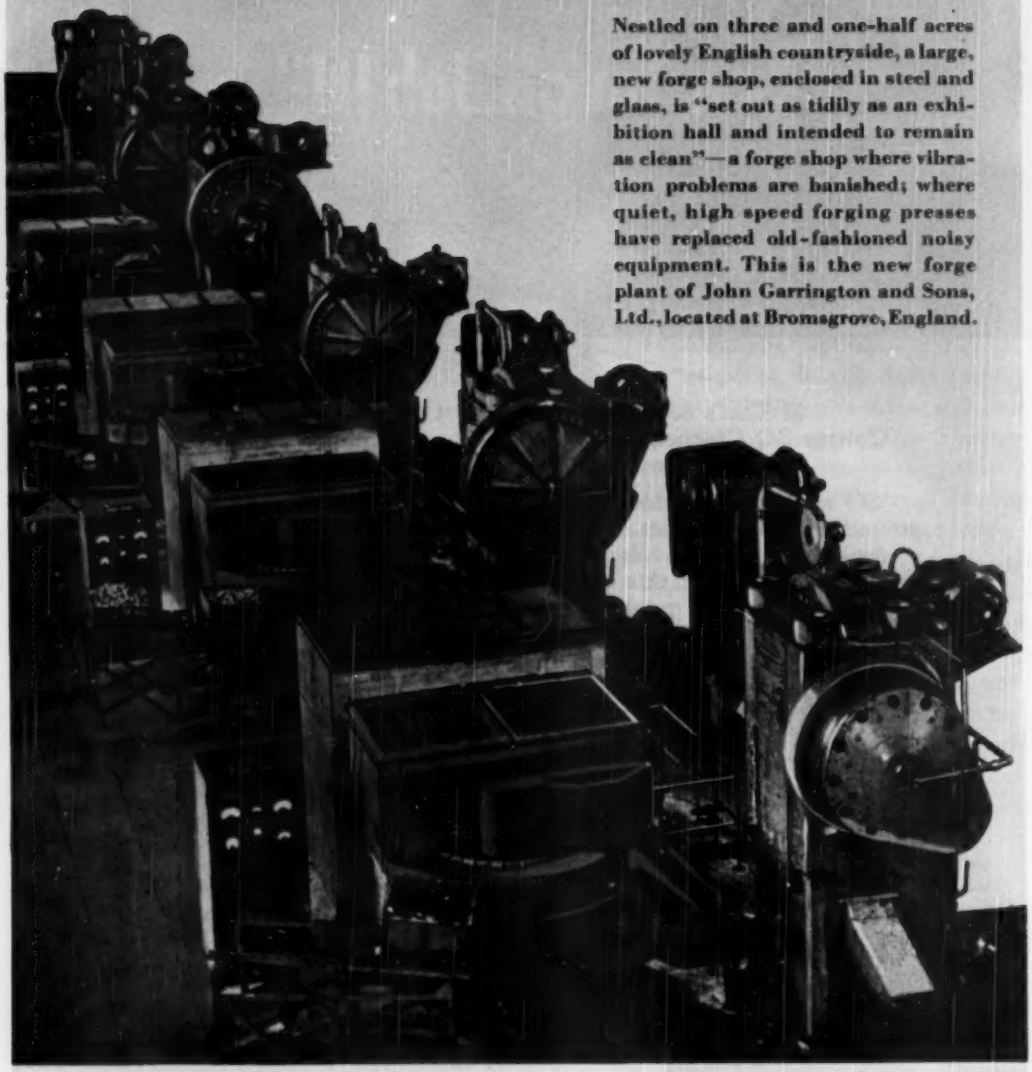
FORGING PROGRESS

Garrington's Great New

Nestled on three and one-half acres of lovely English countryside, a large, new forge shop, enclosed in steel and glass, is "set out as tidily as an exhibition hall and intended to remain as clean"—a forge shop where vibration problems are banished; where quiet, high speed forging presses have replaced old-fashioned noisy equipment. This is the new forge plant of John Garrington and Sons, Ltd., located at Bromsgrove, England.



Presses shown above are only part of the battery of twelve high speed forging presses comprising the entire capacity of the Garrington Bromsgrove Forge.

IN GREAT BRITAIN:

All-Press Forge Plant!

This forge shop is equipped only with twelve forging presses, yet it produces 20,000 tons of steel forgings yearly. NATIONAL High Speed Forging MAXIPRESSES were chosen because they are the world's most efficient mechanical forging presses, possessing unequalled rigidity and reliability in operation. Outstanding advantages of MAXIPRESSES over old-fashioned forging equipment include:

1 Higher production

2 Lower maintenance cost

3 Longer die life

4 Less noise and vibration

5 Lower skill requirement

NATIONAL is proud *also* of the part its extensive ENGINEERING ASSISTANCE and SERVICE have played in making this installation a successful one. This is in line with NATIONAL'S long-standing policy of following its machinery through to trouble-free operation.

NATIONAL No. 7½ MAXIPRES, weighing 880,000 pounds, in operation in the Garrington plant.

Here is another example of how MAXIPRESSES are used to produce superior forgings at lower cost. Let us help you investigate the application of high speed forging presses to your work. No obligation, of course.

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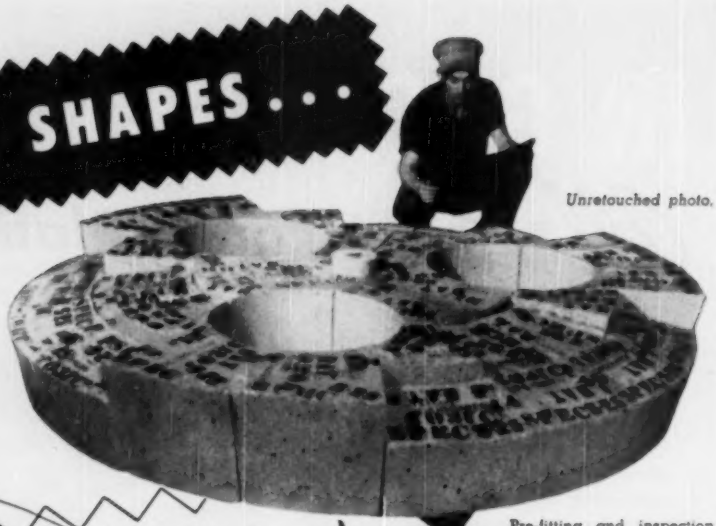

Unretouched photo.

Pre-fitting and inspection of a Taylor Sillimanite (TASIL) Electric Furnace Roof prior to shipment from the Chas. Taylor plant.

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HERE'S THE PATTERN OF *Taylor service*

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3. Produce under strict control.
4. Fire in modern periodic or tunnel kilns.
5. Finish, assemble and mark to identify.

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1. A shape or complete assembly engineered for *your* job.
2. *Time saved*—pre-fitting means quick, accurate installation with minimum cutting and fitting on the job.
3. *Money saved*—through lower masonry cost; longer refractory life; uninterrupted production.

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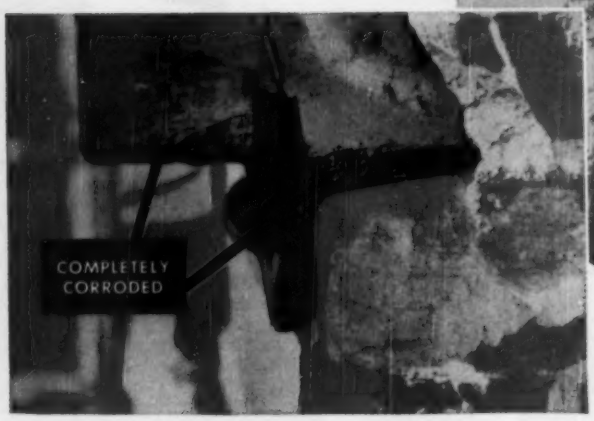
RED LEAD "outstanding"

. . . as a protective coating for enclosed structural steel



An example of corrosion damage due to lack of paint protection on structural steel in a building. Photograph at left indicates one of the badly rusted beams. Small pieces of steel laid on top of the beam are portions of other members which had corroded completely. Photograph above shows the bad pitting found on the columns.

CORROSION DIFFICULTIES, arising from condensation of moisture between the interior and exterior walls of steel housing units, require that structural members be protectively coated to prevent damage to the strength properties of the structure.

Since coating systems vary in their effectiveness for this purpose, thirty-four kinds of available paint systems were tested under conditions simulating those expected to be encountered in actual service. Evaluation of protectiveness was based on corrosion resistance to (1) continuous immersion in water, (2) contact with air at high humidity, (3) continuous condensation, (4) alternate wet-dry conditions, and (5) continuous contact with insulation in the presence of water. Tests were conducted on triplicate panels for each coating system, two panels in the as-painted condition and one intentionally damaged by scratching it lengthwise through the paint film to the steel. In the case of damaged films immersed in water for 3000 hours—the most severe test condition—these tests showed:

"*Only System* C (red lead) offered protection to the bare steel in the damaged zone. In fact, for the majority of the other systems, continued exposure would have resulted in actual perforation of the base metal in this area in a relatively short period of time.

"Considering all factors in rating the various coatings, *System* C (red lead) appears to be outstanding. It has a good blister rating, it affords excellent protection to the base metal, as evidenced by low weight loss and slight visual evidence of attack on the steel and, as previously mentioned, penetration and undercutting at the damaged zone are either negligible or slight."

No other metal-protective paint has ever known such wide acceptance by industry through the years as red lead. And, as the afore mentioned tests again proved, the value of red lead as a corrosion inhibitive pigment is most fully realized in a paint where it is the only pigment used.

Data from "A Study of Paints for Enclosed Structural Members in Steel Housing Construction"—a technical report on a comprehensive investigation recently conducted at Battelle Memorial Institute under the sponsorship of the American Iron and Steel Institute.

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Bulletin on SUPER REFRACTORIES

by CARBORUNDUM
TRADE MARK

NO. 11 OCTOBER, 1950

Why is a Variety of Super Refractories Desirable?

A wide range of refractory properties is required in modern furnaces. Resistance to slags, spalling, cracking, mechanical abrasion, flame erosion, and high temperatures are needed. Chemical inertness, load carrying ability and high thermal conductivity are also called for. Light weight, high density, low permeability and insulating qualities are often required.

Obviously, no single super refractory can embrace all of these features. Therefore, a variety is needed in order to provide the best possible combination of features for each particular set of operating conditions.

The table below indicates only the major classes of super refractories by CARBORUNDUM. Each product class must necessarily consist in turn of many *types*. A silicon carbide refractory, for instance, may be the proper material for a job providing that certain of its properties can be enhanced. To best meet such requirements, a special *type* of CARBOFRAX silicon carbide refractory must be available.

In order to meet this wide range of demands The Carborundum Company has developed a large variety of super refractories. Today, more than 60 standard types of CARBOFRAX materials are available. Other product groups have been extended proportionally.

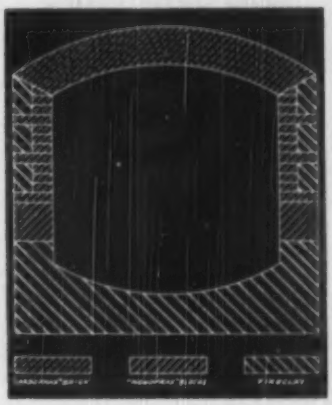
Physical Properties of Super Refractories by CARBORUNDUM
Trade Mark

	CARBOFRAX Silicon Carbide	MULLFRAX Electric Furnace Mullite	MULLFRAX S Converted Kyanite	ALFRAX K	ALFRAX B	ALFRAX BI
				Electrically Fused Alumina		
Heat Conductivity at 2200° F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25° — 1400° C.)	.0000044	.0000059	.0000049	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2460° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 in. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.

Twin Problems Here — Abrasion and Heat

It used to be necessary to patch the side walls of these coke fired forge heating furnaces every day and rebuild brickwork every two to three days. Used for heating caps to be welded on drilling bars, the sidewalls were subjected to 2700°-2800° F. along with considerable abrasion as parts hit the walls. However, since the installation of eight courses of CARBOFRAX silicon carbide brick in each side wall, patching is necessary now only once a month and rebuilding only after three to four months of continuous operation.

The right combination of properties of the CARBOFRAX brick used have best fulfilled these service requirements.



Two Types of Super Refractories Best Service Reverbatory Furnace

This is a cross-sectional view of a typical reverberatory type, rock wool furnace using super refractories by CARBORUNDUM to advantage.

To withstand the extreme corrosion encountered at the slag line, MONOFRAX K fused cast blocks are used in

"Carborundum," "Carbofrax," "Mullfrax," "Monofrax," "Alfrax" are registered trademarks which indicate manufacture by The Carborundum Company

Address all correspondence to: Dept. C-100, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

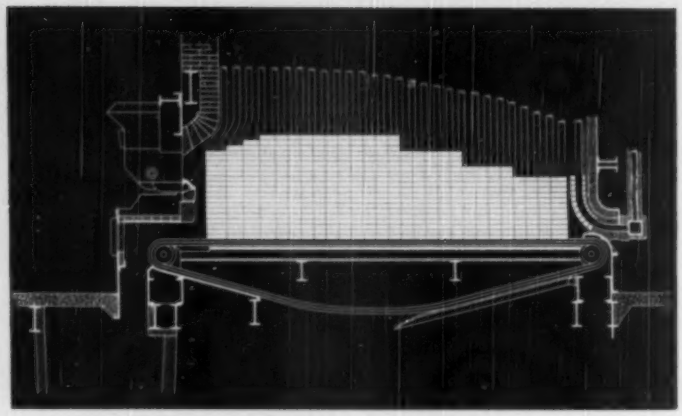
Continued on other side →

← Continued from other side

this area. Being a fused cast high alumina product, this material is extremely dense, thus avoiding erosion by the basic charge. It is also highly refractory, having a fusion point of over 3500° F.

Above the MONOFRAX blocks, CARBOFRAX brick are used in the side walls and arch to withstand the extreme temperatures and cutting action of the flame. As there is no softening of the hard, dense CARBOFRAX brick, deformation of the walls is avoided — maintenance cost is minimized. Also, the high thermal conductivity of these brick is used to dissipate heat in certain areas.

As is apparent here, complex service conditions — even in one furnace — often demand a combination of super refractories to meet these needs.



Job-Designed Super Refractory Aids Boiler Operation

Illustrated is a typical spreader stoker fired boiler equipped with water walls and a traveling grate. The water tubes are faced with CARBOFRAX silicon carbide blocks.

Here are the several advantages of using CARBOFRAX blocks: they protect the tubes from the abrasive action of the fuel and clinkers on the traveling grate; they protect the tubes from fuel impingement; they prevent slag from forming between the tubes and hampering operations; and they conduct the heat rapidly from the firebox to the water tubes. These operating benefits result from the specialized properties of CARBOFRAX blocks developed particularly for this type of service.

Ceramic Operation Demands Special Type Super Refractory

This is a typical car superstructure used by a manufacturer of electrical porcelains and insulators. The kiln is operated on a 48 hr. cycle at temperatures up to 2240° F. Due to the kiln construction, the furniture is subjected to severe heat shock at the entrance. Yet at the time of this picture, the CARBOFRAX setter tile had averaged 150 trips and were still in use. Moreover, in a 10 month operating period only two cars had to be rebuilt.

This excellent performance is attributed to the use of a special variety of CARBOFRAX tile. They have exceptional resistance to heat shock and can carry heavy loads at high temperatures. (Note that the tile are still straight and true.) Also, the high thermal conductivity of the thin section CARBOFRAX tile insures uniform burning of the ware, and reduces under- and over-firing losses. Ware sticking is avoided, too, since these tile remain free from boiling or blistering.

Regardless of the type of ceramic operation there is a super refractory by CARBORUNDUM with the right combination of special properties to give the most economic results.

4 Different Super Refractories Improve Enameling Furnace Operation

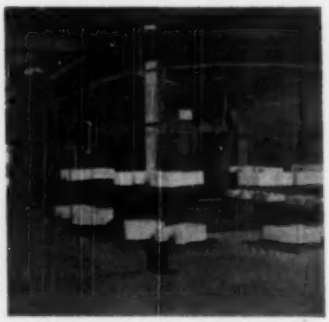
To meet all of the conditions found in the various zones of this continuous enameling furnace, four types of super refractory are needed.

The side walls and hearth of the muffle are made of two varieties of CARBOFRAX silicon carbide tile. The lower thermal gradients through the muffle tile reduce the temperature heads. Thus, working temperatures are attained with less fuel input. With the greater temperature uniformity there are fewer rejects.

The support arches and pier facings are made from MULLFRAX electric furnace mullite material to best meet service conditions in the combustion chamber.

ALFRAX aluminum oxide side rail tile are used to support the muffle side walls. These tile are chemically inert and have more than enough strength to carry the side wall load.

By proper combination of these super refractories, the operator of this furnace has increased production and decreased fuel and maintenance costs. These exceptional results are made possible through a wide variety of super refractories by CARBORUNDUM from which to select.



To obtain facts and figures on installations in specific fields merely select from this list of bulletins. Copies will be sent you at once. No obligation, of course.

Super Refractories by CARBORUNDUM (general catalog)
Super Refractories for the Ceramic Industry
Super Refractories for the Process Industry
Super Refractories for Boiler Furnaces
Super Refractories for Heat Treatment Furnaces
Super Refractories for Gas Generators
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- EXCELLENT WELDABILITY
- HIGH CORROSION RESISTANCE

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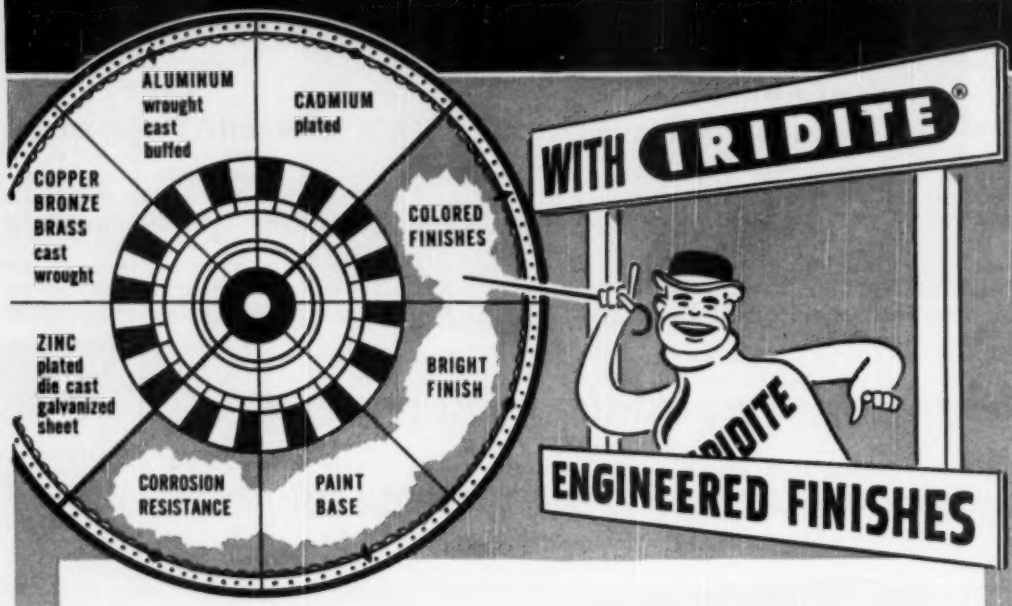

Spin the wheel for any type of chemical finish on non-ferrous surfaces... plated, die cast, galvanized, or sheet . . . and there's an Iridite to provide corrosion resistance, a base for paint or to produce an attractive, eye-appealing finish in a variety of colors.

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For every Spencer Turbo in service in a list of 62 large industrial plants in 1940, there were two more Spencers in service on January 1st, 1950. The horse-power of Spencer Turbos in these plants tripled in ten years.

Some of these Turbos have been operating satisfactorily for more than a quarter of a century and all of them have the well-known Spencer simplicity and reliability which is mainly responsible for such an unusual demonstration of confidence.

Design engineers appreciate the light weight, all-metal construction and the absence of noise and vibration which enable them to mount the Spencer Turbo on or under machines or overhead and out of the way. Leading furnace and oven manufacturers prefer to have the air supplied by Spencer Turbos because of their efficiency and reliability. Maintenance engineers everywhere appreciate that the wide clearances, with only two bearings to grease, means long life with extremely low maintenance costs.

LOW MAINTENANCE

Repeated analyses of repair costs indicate that the average cost of replacement parts for Spencer Turbos is less than one dollar per machine per year. This is merely another proof of the well-known and widely accepted fact that Spencer Turbos are extremely reliable.

THE AVERAGE COST FOR REPAIR PARTS IS ONE DOLLAR PER MACHINE PER YEAR

APPLICATIONS

Spencer Turbos are made in standard capacities from 35 to 20,000 cu. ft., 1/3 to 800 HP and 8 oz. to 10 lbs. pressure. The principle uses are to furnish low pressure air for oil and gas fired Heat Treating Furnaces, Foundry Cupolas, Agitation of Liquids, Gas Boosters, Engine Testing, Ventilation and Cooling.

See Spencer at Booth No. 1019

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONNECTICUT

SPENCER
HARTFORD

HYDRAULIC
PRESSES

for

FABRICATING POWDERED METALS

RE-SIZING POWDERED METAL PARTS

PREFORMING IN PLASTICS

by

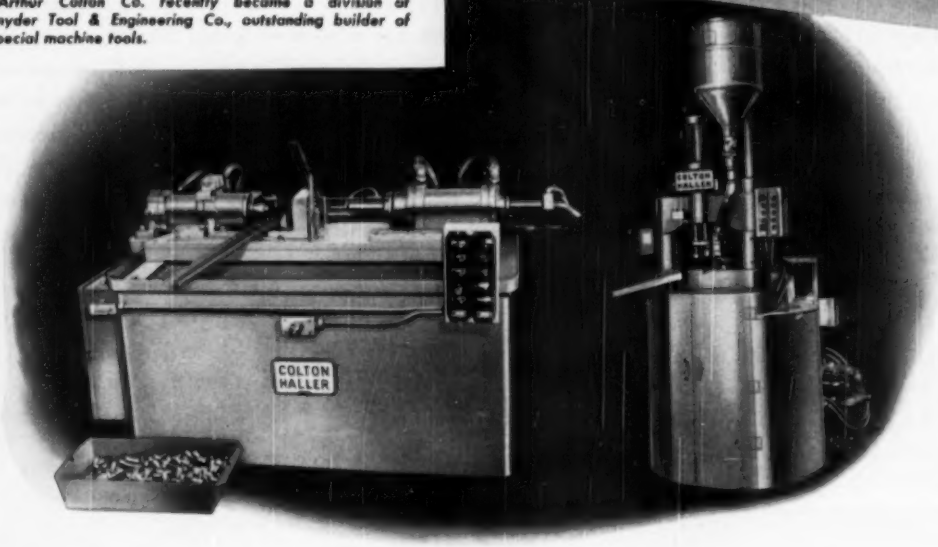
COLTON HALLER

Arthur Colton Company*, America's oldest builder of rotary and single punch presses, and plastic preforming presses, is now building Colton-Haller Hydraulic Presses in capacities of 25, 40, 100, and 125 tons. (Proposals on higher tonnages on request.)

These presses, for fabricating and sizing powdered metal parts, incorporate original developments which are protected by many patents, granted and pending, in the United States and abroad.

If interested in the economy, precision, strength, uniformity and versatility of powdered metal fabrication, we invite your inquiry.

**Arthur Colton Co. recently became a division of Snyder Tool & Engineering Co., outstanding builder of special machine tools.*



ARTHUR COLTON COMPANY

Specialists in Press Building for 65 Years

Div. SNYDER TOOL & ENGINEERING CO. • 3415 E. Lafayette • Detroit 7, Michigan

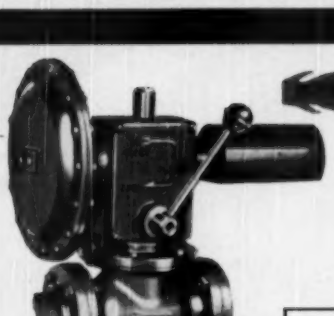
Offices in Principal Cities

for the Newest in Gas-Fired Industrial equipment

See McKee Eclipse Booth 927, at the Metal Show

CHICAGO OCT. 22-27

Back of every one of these New McKee-Eclipse Products is more than 30 Years Experience with combustion equipment designed for all types of applications and burning any type gas or combination of gases.

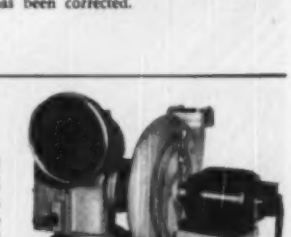


Series "LT" McKee-Eclipse LOCK-TITE Safety Valve

Generally acclaimed as one of the most unusual and important developments in recent years in the industrial gas field! Makes possible for the first time, instantaneous Gas Shut-Off under *any* or *all* unsafe conditions. As a *double* protection, when the gas valve has snapped shut due to an unsafe condition, *it* must be opened manually, and only after the unsafe condition has been corrected.

McKee Consta-Mix Proportioning Valve

The very latest in a wide selection of McKee Air-Gas Mixers, L-P Proportional Mixers and Diluter Valves. Permits minute adjustment of the air-gas mixture at any point in valve capacity, and independent of pressure or other fluctuations.



Series "PW" McKee-Eclipse Piloted Wall-Tite Burners

Another remarkable McKee-Eclipse Advancement! A Sealed Burner with Flame Failure Protection and Constant Blast Pilot. Particularly suitable for low temperature applications or where burners are in a "difficult-to-light" location.

Send for Bulletins on Products in which you are interested

Super-Matic Scotch "Steamboilerplants"

These new Scotch Marine Boilers (13 years field-tested) are part of an extensive line of McKee Automatic Gas-Fired "Steamboilerplants" 12 to 100 H.P., in vertical and horizontal models. "Complete package" ready to connect up, and operate at the push of a button.

Series "G" with Gas-Pak Combustion Unit

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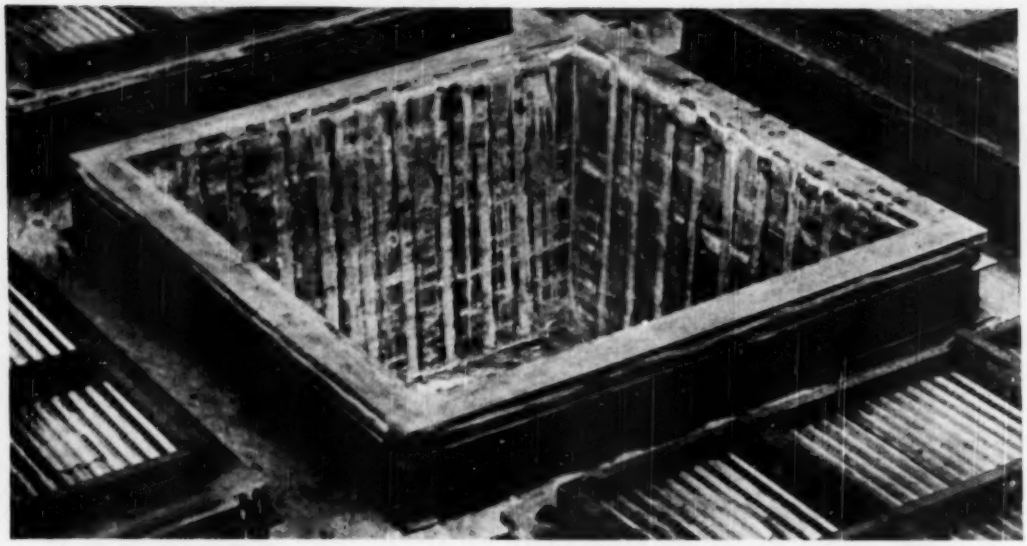
McKee Eclipse

R-5272

SUPERINTENDENT REPORTS:

"5 YEARS OF HARD USE AND NOT A CENT FOR MAINTENANCE"

on these slow-cooling pits made of Lumnite* Refractory Concrete



Nine slow-cooling pits in McKees Rocks, Pa., plant of Carnegie-Illinois Steel Corporation show how monolithic Lumnite Refractory Concrete is used to resist wear and tear at high temperatures. Pits are 14' x 14' x 6', inside dimensions. Walls taper 13" to 20" thick, top to bottom. Built by Rust Furnace Co., Pittsburgh, Pa.

Absorbing sudden thermal shocks as red-hot railroad car axles (often up to 1600°F.) are lowered into them—constantly battered as the heavy axles are charged and unloaded—these slow-cooling pits have required no maintenance in five years.

An unusual case? Not at all. It's typical of many in our files. And the reason is: concrete pits made with Lumnite calcium-aluminate cement and firebrick grog are heat-resisting and jointless. The refractory properties protect against high temperatures; the monolithic walls replace hundreds of small construction units with vulnerable edges and joints which can work loose.

Construction costs are lowered, too. Lumnite Refractory concrete can be placed by unskilled labor. No fitting or trimming of small units, no daubing with mortar. Reinforcing rail-sections are easily built in.

Lumnite is "the adaptable refractory" because, with selected aggregates, it can be cast into any size, shape or thickness. This speeds construction. And when repairs are necessary, they can be made quickly since Lumnite reaches full strength in 24 hours.

Send for further information on time- and money-saving Lumnite Cement. Write to Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N.Y.

SPECIFY CASTABLE REFRACTORIES MADE WITH LUMNITE

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MPL-33

ATLAS **LUMNITE for INDUSTRIAL CONCRETES**

REFRACTORY, CORROSION-RESISTANT, INSULATING, OVERNIGHT

A UNIVERSAL ATLAS PRODUCT

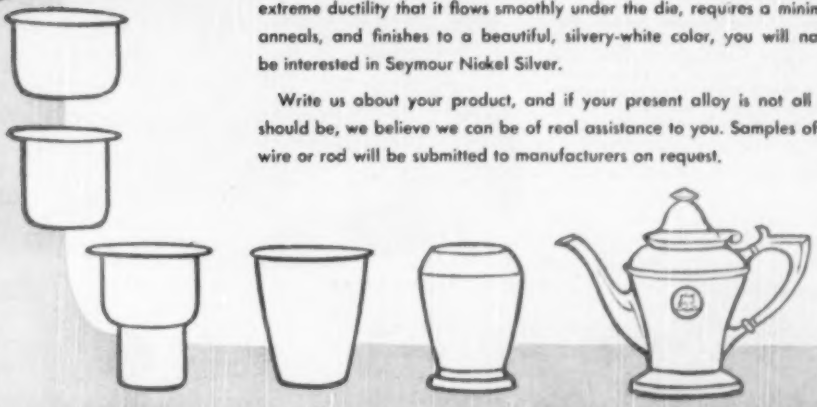
"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—NBC Network*

SEYMOUR Nickel Silver

is a Natural for deep draws

Your product may not be hollowware — but if you need an alloy of such extreme ductility that it flows smoothly under the die, requires a minimum of anneals, and finishes to a beautiful, silvery-white color, you will naturally be interested in Seymour Nickel Silver.

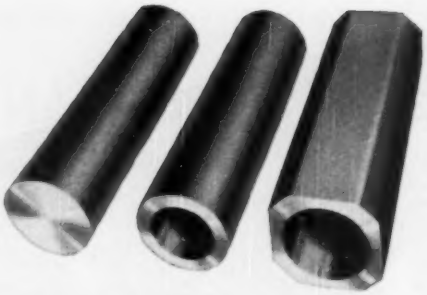
Write us about your product, and if your present alloy is not all that it should be, we believe we can be of real assistance to you. Samples of sheet, wire or rod will be submitted to manufacturers on request.



THE SEYMOUR MANUFACTURING COMPANY, SEYMOUR, CONN.

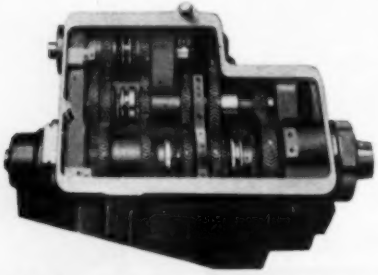
SEYMOUR

Tumbling Barrels . . to Resist Corrosion and Abrasion. These barrels are subject to extreme wear from small parts being cleaned by the swirling agitation of caustic solution and abrasives. For extra-long life, they are fabricated from wear- and corrosion-resistant Ampco Grade 8 sheet, carbon-arc welded with 5/32" Ampco-Trode 160 coated electrodes used as filler rods.

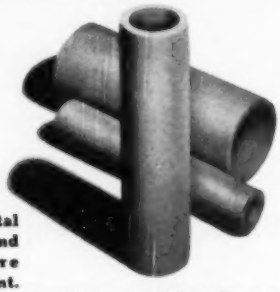


Ampco Extrusions available as solid rod and/or tube in rounds or simple shapes. From Ampco's own 2275-ton hydraulic press and extrusion mill. Their use saves metal, machining time, and costs. Superior grain structure and exceptionally high strength are assured — *plus* close tolerances and good surface finish.

Ampco Metal Cam . . . for Smooth Action, Extreme Wear-Resistance. Ampco Grade 20 selected because it actually outlasts hardened steel with twice the Brinell hardness. This is due to its extreme wear-resistance and the smoother action of bronze against steel. Also ideal for rollers, gibs, slides, wearplates, forming dies on light-gauge steel and welding jaws.



Ampco Bushings on High-Speed Headstock . . . for High Wear-Resistance. There are 16 Ampco Grade 18 Bushings in this one headstock: 14 on loose-running gears, 2 on the center bearing of the intermediate shaft and main spindle. Ampco Grade 18 chosen as ideal alloy because of the heavy gear loads and high spindle speeds. Extra life assured by high tensile (77-85,000 psi), and Brinell hardness of 159-183.



Stock Bars of Grade 18 Ampco Metal . . . for Production and Maintenance where long life is important. Wear-resistant. Have exceptional impact and fatigue characteristics. Centrifugally cast to provide dense, fine grain structure free from impurities. Readily machinable. Ideal for bearings, bushings, gears, worm wheels, slides, guides and other wear applications. Available from stock in 12½-inch lengths from 2½-inch to 6-inch OD, or solid bars ½" to 4½" diameter, cut to desired lengths.

Paper Mill Rolls . . Wear-Resistant for Longer Service. Weight and wear are the usual problems in such rolls. Both were licked in this case — with Ampco aluminum-bronze. Centrifugally-cast Ampco Metal Grade A-3 provided a light, hollow roller — resistant to both wear and corrosion. Shaft and end-plates were cast of the same alloy and welded to the roller with corrosion-resistant Ampco Trode 10 electrodes.

Cast Ampco Metal Pump Bodies . . . for Corrosion-Resistance. Ampco Grade 12 selected for its high resistance to corrosion and wear (which is a special quality of all Ampco Metals). Grade 12 also has the advantage of quick, easy seating for valve and pump parts. Meets Federal specification QQ-B-671a, Class A, and Navy specification 46-B-18c.

AMPCO

Equipment Life--Lower Costs with AMPCO Bronze Parts

Specify Ampco aluminum bronze for these unique, money-saving properties:

1. High tensile strength
2. High compressive strength
3. High impact and fatigue values
4. Excellent bearing qualities
5. High "strength to weight" ratio
6. Resistance to wear and corrosion
7. Good retention of values at temperature extremes

It pays to use Ampco aluminum bronzes wherever you can. These long-wearing bronze alloys assure longer life and better service for almost any part — reduce maintenance and replacement frequency, cut downtime losses to a minimum!

First of all, be sure to specify Ampco bronzes for your own products. They're a mark of extra-quality which all buyers recognize. By the same token, look for Ampco bronze parts as a mark of extra-value in the equipment which you buy. And of course, use Ampco bronze replacements in your own plant maintenance to reduce downtime, service and repairs, and to insure low-cost, trouble-free operation.

Make Ampco Bronze Parts a "must" in every plan — product or production. That way you're sure of lower costs. Send for complete information today.

Ampco aluminum bronze and other Ampco copper-base alloys are available in a variety of grades to meet your exact requirements in any form you need: rolled sheet or plate, sand or centrifugal castings, forgings or extrusions, arc- and resistance-welding electrodes, and corrosion-resistant centrifugal pumps and plug valves.

Free . . .
Cost-cutting information! Tear out this coupon and mail today.

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Tear out this coupon and mail today!

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Send me your free Bulletin giving full details of cost-saving physical properties of Ampco aluminum-bronze alloys.

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9-4

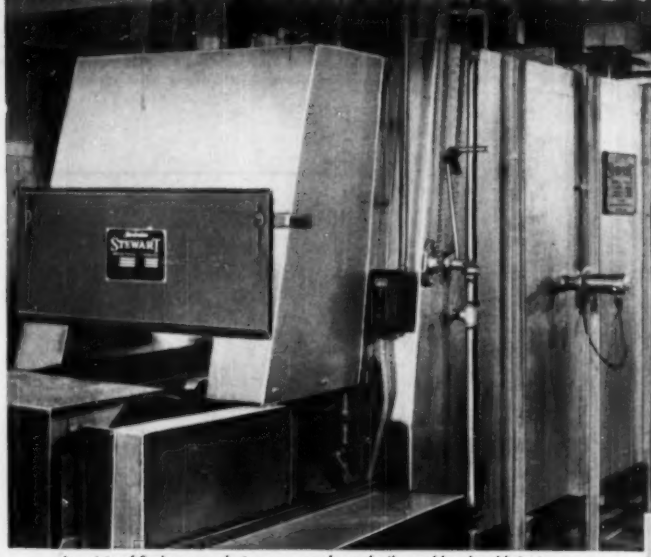
No. 101 of a Series of Typical Installations

Sunbeam STEWART

THE BEST INDUSTRIAL FURNACES MADE

HOW SUNBEAM STEWART FURNACES HELP MANUFACTURERS REDUCE COSTS AND KEEP THEMSELVES COMPETITIVE

COPPER BRAZING... SILVER SOLDERING.. BRIGHT ANNEALING ALL-IN-ONE UNIT



A variety of Sunbeam products are copper brazed, silver soldered and bright annealed in this versatile Sunbeam Stewart Continuous Electric Brazing unit. Result: Increased production, lower operating cost and improved quality.

This is number 101 in a series of typical installations demonstrating the wide variety of specific requirements in the metal-working industry Sunbeam Stewart furnaces are designed to meet. As a division of Sunbeam Corporation, Sunbeam Stewart has the practical advantages of designing furnaces used in the parent plant—working closely with its heat treating problems.

Modern brazing furnaces as built by Sunbeam Stewart enable product designers to employ simplified, practical designs in the production of brazed assemblies. This type of furnace pays for itself quickly through cost reduction in manufacturing operations and economy in mass production. Manufacturers with diversified products require but one brazing furnace for their entire production with equal success. Three Sunbeam Stewart Electric Brazing furnaces, with capacities up to 500 lbs., are used in the parent plant—not only copper brazing assemblies, but also for silver soldering and bright annealing with equally good results. It may pay you to check the advantages of electric furnace brazing. We will be glad to work with you by experimentally brazing samples of your proposed assembly.

Sunbeam Mixmaster's entire base is a brazed assembly. Note the bright sheen of brazed surface.

This sprinkler base is bright annealed while the hose nozzle is silver soldered—all in this same furnace.

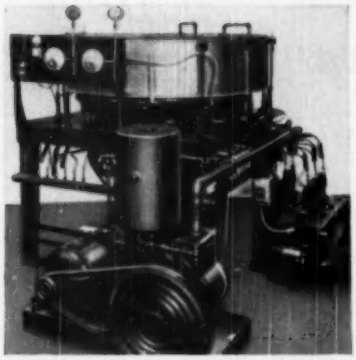
Sunbeam STEWART INDUSTRIAL FURNACE DIVISION of Sunbeam CORPORATION

(Formerly CHICAGO FLEXIBLE SHAFT CO.)

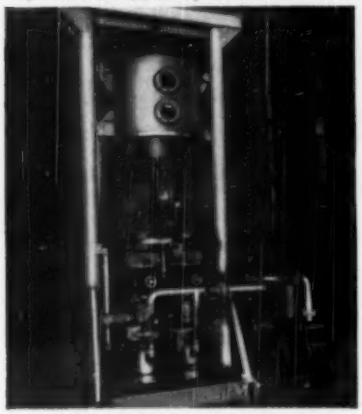
Main Office: Dept. 108, 4433 Ogden Ave., Chicago 23 — New York Office: 322 W. 48th St., New York 19 — Detroit Office: 3049 E. Grand Blvd., Detroit
Canada Factory: 321 Weston Rd., So., Toronto 9

A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM STEWART furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM STEWART engineer will be glad to call and discuss your heat treating problems with you.

First Thought FOR VACUUM!



Eisler Radio Tube Machine showing Kinney Single Stage Pump used for initial pump-down and for backing Eisler Pump. The vacuum exhausting process is fast, sure, and extremely complete . . . making possible longer-lived, better performing tubes.



National Research Corporation high vacuum metallurgical furnace. Kinney Pump used for roughing and for backing diffusion pumps. In high vacuum furnaces metals like Titanium, Zirconium and Molybdenum are being cast or treated in the pure gas-free state. These vacuum-processed metals display new qualities of ductility and conductivity . . . new advantages made possible by Kinney-created low absolute pressures.

When the job calls for vacuum processing, keep *Kinney High Vacuum Pumps* in mind. Thousands and thousands of successful installations prove beyond doubt that it's wise to make Kinney Pumps your first thought for vacuum!

Why do so many modern vacuum processing systems employ Kinney Vacuum Pumps? Because these Pumps save processing time, because they conserve operating costs, and because they can be trusted on the job. If you want fast pump-down and minimum equipment "down-time", the Kinney Pump is the pump you need. Write for Bulletin V45, the complete story on Kinney High Vacuum Pumps and Equipment.

KINNEY MANUFACTURING CO., 3584 Washington St., Boston 30, Mass. Representatives in New York, Chicago, Cleveland, Houston, New Orleans, Philadelphia, Los Angeles, San Francisco, Seattle.

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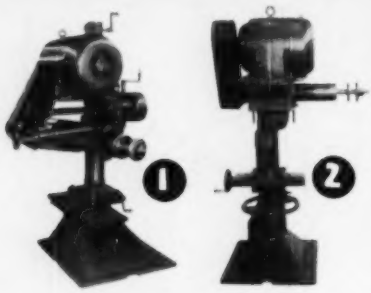
Making old things better
Making new things possible

KINNEY Vacuum Pumps

FOR HIGH PRODUCTION POLISHING and BUFFING

ACME Automatic POLISHING and BUFFING MACHINES



ACME Polishing and Buffing LATHES

Developed from years of experience and successful application to hundreds of polishing and buffing machine arrangements, ACME Adjustable Floating Head Polishing and Buffing Lathes have a record of dependable performance under production conditions.

Used in conjunction with ACME Automatics, Rotary, Straightline, Semi-Automatic and Special polishing and buffing machines, they have proved their leadership for years.

1—ACME Type G-1 Heavy Duty Adjustable Polishing and Buffing Lathe. Up to 20 H.P., also furnished in Standard type up to 7½ H.P.

2—ACME Type L-8-L Buffing Head. Vertical and cross slide adjustment, angle and tilt adjustment. Up to 10 H.P.

3—ACME Heavy Duty Adjustable Double Float Polishing and Buffing Lathe. Horizontal and vertical adjustment. Up to 20 H.P.

4—Acme Type G-3 Heavy Duty Adjustable Floating Head Polishing and Buffing Lathe. Up to 15 H.P.

5—ACME Type G-3 Adjustable Polishing Belt Head Lathe with floating back-up wheel.

6—ACME Standard Type G-3 Adjustable Floating Head Polishing and Buffing Lathe. Up to 7½ H.P.

(Catalogs on Request)

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STRAIGHT LINE
SEMI-AUTOMATIC
AND SPECIAL
Polishing and Buffing
Machinery

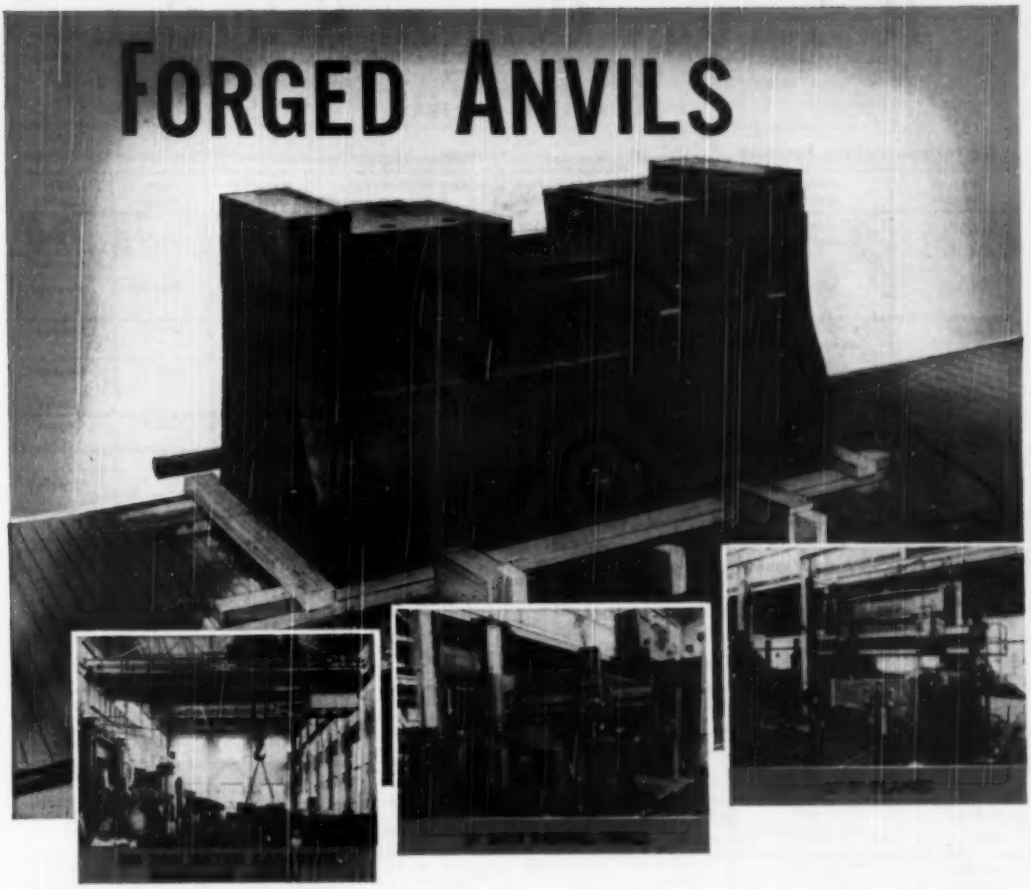
SPECIAL MACHINERY
AMC
AUTOMATIC BUFFING MACHINES

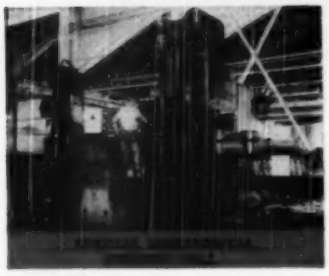
ACME Manufacturing Co.

1645 HOWARD ST. DETROIT 16, MICH.

Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR NEARLY HALF A CENTURY

FORGED ANVILS





For any size or make of Hammer-

THESE Modern Specialized facilities are producing forged anvils to fit any size or make of hammer for forge shops making automotive, aviation and industrial forgings. Here within our plant are complete modern machining facilities for handling forged anvils for replacements to your present equipment. And you can order forged anvils on new Erie Hammers of your selection as well. We welcome your inquiries.

ERIE FOUNDRY COMPANY • ERIE, PA • U. S. A.

ERIE

ERIE BUILDS *Dependable* HAMMERS

Refractory Cement Selection Made Easy

for ferrous melting furnaces

Type of furnace	metals melted	use of cement	Norton number	cement recommended description	maturing temp.	max. temp.	how applied
indirect arc	alloy iron and malleable iron	lining	RA1144	coarse grain Alundum* cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		rammed
		troweling around electrodes	RA162	fine grain Alundum cement	1850°F	2950°F	troweled
direct arc	alloy steel and malleable iron	lining roof and around electrodes	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		lining roof and around electrodes	RA1195	very coarse grain Alundum cement	2000°F	3100°F	rammed
		patching	RA1160		1850°F		rammed
high frequency induction	stainless steel and refractory alloys	lining	RM1169	very coarse grain Magnorite* cement	2100°F	3250°F	rammed (dry)
		patching large furnaces	RM868	medium grain Magnorite cement	2200F°	2750°F	rammed
		patching small furnaces	RM1171	medium grain Magnorite cement	2000°F	2900°F	troweled or rammed
for non-ferrous metal-melting furnaces							
low frequency induction	refractory alloys, cupronickel, nickel silver, high copper alloys Al, Te, Si bronzes	lining	RM1140	coarse grain Magnorite cement	2300°F	3250°F	rammed
	nickel silver	lining	RA1195	very coarse grain Alundum cement	2000°F.	3100°F	rammed
	brasses not more than 90% copper or less than 10% zinc	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
indirect arc	nickel and high nickel alloys	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		
crucible melting furnaces■	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon* cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed
reverberatory furnaces▼	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed

■ Cement not in contact with metal, used in combustion chamber.
▼ Cement in contact with metal. * Trade-marks Reg. U. S. Pat. Off. and Foreign Countries.

This Chart is a synthesis of several charts from a new 16-page bulletin just prepared by Norton refractory engineers, after exhaustive laboratory and field tests.

Titled "Norton Longer Lasting Refractory Cements," this fact-packed bulletin covers the properties, selection and application of the correct cement for your refractory requirements.

Write for Bulletin 863. Norton Company, 320 New Bond Street, Worcester 6, Mass.

NORTON

Making better products to make other products better

Special REFRACTORIES

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METAL PROGRESS

The Magazine for Metallurgical Engineers

Vol. 58 *October, 1950* *No. 4*

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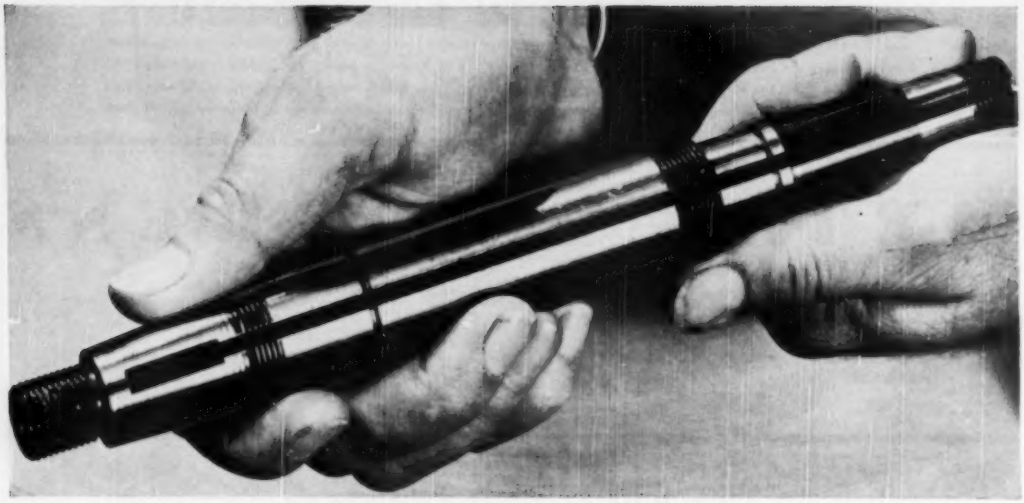

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• CONSOLIDATED PROGRAM •

32nd National Metal Congress

AMERICAN SOCIETY FOR METALS

INSTITUTE OF METALS DIVISION,
AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS (A.I.M.E.)

AMERICAN WELDING SOCIETY (A.W.S.)

SOCIETY FOR NON-DESTRUCTIVE TESTING (S.N.D.T.)

Saturday, October 21, 1950

9:30 A.M. and 2:00 P.M. Seminar: Atom Movements; Normandie Lounge, Stevens Hotel

Sunday, October 22, 1950

9:30 A.M. and 2:00 P.M. Seminar: Atom Movements; Ballroom, Palmer House

3:00 P.M. A.W.S. President's Reception; Ballroom, Sherman Hotel

7:30 P.M. A.I.M.E. Program Committee; Rooms 809-810, Sheraton Hotel

8:00 P.M. Sales Clinic; Ballroom, Palmer House

Monday, October 23, 1950

Exposition Open 12:00 Noon to 10:30 P.M.

9:00 A.M. A.I.M.E. Plastic Deformation; Boulevard Room, Sheraton Hotel

9:30 A.M. Surface Phenomena; Ballroom, Palmer House

9:30 A.M. A.W.S. Weldability; Ballroom, Sherman Hotel

9:30 A.M. A.W.S. Resistance Welding; Louis XVI Room, Sherman Hotel

9:30 A.M. A.W.S Surfacing, Crystal Room, Sherman Hotel

2:00 P.M. High Production Session: Nonferrous Fabrication; Saddle and Sirloin Club, International Amphitheatre

2:00 P.M. Physical Metallurgy; Ballroom, Palmer House

2:00 P.M. A.W.S. Flame Hardening; Crystal Room, Sherman Hotel

2:00 P.M. A.W.S. Arcs, Electrodes and Fluxes; Louis XVI Room, Sherman Hotel

2:00 P.M. A.W.S. Research; Ballroom, Hotel Sherman

2:00 P.M. A.W.S. Panel Discussion: Resistance Welding; Bal Tabarin Room, Sherman Hotel

2:00 P.M. A.I.M.E. Recrystallization and Annealing Textures; Boulevard Room, Sheraton Hotel

2:00 P.M. A.I.M.E. Structure of Alloys; Tropical Room, Sheraton Hotel

4:00 P.M. A.I.M.E. Membership Committee; Rooms 809-810, Sheraton Hotel

4:15 P.M. First Lecture: High-Temperature Properties; Ballroom, Palmer House

Monday's Program, Continued

4:30 P.M. A.W.S. Lecture: Aluminum; Louis XVI Room, Sherman Hotel

4:45 P.M. Second Lecture: High-Temperature Properties; Ballroom, Palmer House

5:30 P.M. Third Lecture: High-Temperature Properties; Ballroom, Palmer House

7:30 P.M. A.I.M.E. Panel Discussion: Precipitation Hardening; Tropical Room, Sheraton Hotel

8:00 P.M. A.W.S. Adams Lecture; Ballroom, Sherman Hotel

8:00 P.M. Fourth Lecture: High-Temperature Properties; Ballroom, Palmer House

9:00 P.M. Fifth Lecture: High-Temperature Properties; Ballroom, Palmer House

Tuesday, October 24, 1950

Exposition Open 12:00 Noon to 10:30 P.M.

9:00 A.M. A.I.M.E. Transformations; Tropical Room, Sheraton Hotel

9:00 A.M. A.I.M.E. Properties of Alloys; Boulevard Room, Sheraton Hotel

9:30 A.M. High-Temperature Metallurgy; Ballroom, Palmer House

9:30 A.M. A.W.S. Pipe Fabrication; Crystal Room, Sherman Hotel

9:30 A.M. A.W.S. Resistance Welding; Louis XVI Room, Sherman Hotel

9:30 A.M. A.W.S. Ship Structure; Ballroom, Sherman Hotel

9:30 A.M. S.N.D.T. Technical Session; Morrison Hotel

12:00 M. Canadian Luncheon; Palmer House

12:00 M. Battelle Alumni Luncheon; Palmer House

12:00 M. Gas Appliance Manufacturers Association Luncheon; Stock Yard Inn, International Amphitheatre

12:15 P.M. A.I.M.E. Executive Committee Luncheon; Room 815, Sheraton Hotel

12:30 P.M. A.W.S. Special Design Luncheon; Bal Tabarin Room, Sherman Hotel

2:00 P.M. High Production Session: Hot and Cold Forming of Metals; Saddle and Sirloin Club, International Amphitheatre

2:00 P.M. High-Temperature Metallurgy; Ballroom, Palmer House

2:00 P.M. A.W.S. Resistance Welding; Crystal Room, Sherman Hotel

Tuesday's Program, Continued

2:00 P.M. A.W.S. Design; Louis XVI Room, Sherman Hotel

2:00 P.M. A.W.S. Ship Structure; Ballroom, Sherman Hotel

2:00 P.M. A.I.M.E. Metal-Gas Reactions; Boulevard Room, Sheraton Hotel

2:00 P.M. A.I.M.E. Solidification, Thermal Expansion and Ductility; Tropical Room, Sheraton Hotel

2:00 P.M. S.N.D.T. Technical Session; Morrison Hotel

4:15 P.M. ⊖ First Lecture: Interpretation of Tests and Correlation With Service; Ballroom, Palmer House

4:30 P.M. A.W.S. Lecture: Copper; Louis XVI Room, Sherman Hotel

5:15 P.M. ⊖ Second Lecture: Interpretation of Tests and Correlation With Service; Ballroom, Palmer House

6:00 P.M. A.I.M.E. Cocktail Party; Tropical Room, Sheraton Hotel

7:00 P.M. A.I.M.E. Annual Fall Dinner; Boulevard Room, Sheraton Hotel

8:00 P.M. A.W.S. Symposium: Applied Welding Engineering; Bal Tabarin Room, Sherman Hotel

8:00 P.M. S.N.D.T. Symposium: Radio-Isotopes; Morrison Hotel

8:00 P.M. ⊖ Third Lecture: Interpretation of Tests and Correlation With Service; Ballroom, Palmer House

9:00 P.M. ⊖ Fourth Lecture: Interpretation of Tests and Correlation With Service; Ballroom, Palmer House

Wednesday, October 25, 1950

Exposition Open 12:00 Noon to 10:30 P.M.

8:00 A.M. ⊖ Chapter Chairmen's Breakfast; Palmer House

8:30 A.M. American Gas Assoc. Industrial Gas Breakfast; Stevens Hotel

9:30 A.M. ⊖ Annual Meeting; Ballroom, Palmer House

9:30 A.M. A.W.S. Research; Louis XVI Room, Sherman Hotel

9:30 A.M. A.W.S. Symposium: Education; Ballroom, Sherman Hotel

9:30 A.M. A.W.S. Structural; Crystal Room, Sherman Hotel

10:00 A.M. ⊖ Campbell Memorial Lecture; Ballroom, Palmer House

12:00 M. Alumni Luncheons; Palmer House

12:00 M. Naval Research Laboratory Alumni Luncheon; Palmer House

12:15 P.M. A.I.M.E. Powder Metallurgy Committee Luncheon; Rooms 809-810, Sheraton Hotel

2:00 P.M. ⊖ High Production Session: Cutting of Metals; Saddle and Sirloin Club, International Amphitheatre

2:00 P.M. ⊖ Heat Treatment; Ballroom, Palmer House

2:00 P.M. A.W.S. Machinery and Maintenance; Louis XVI Room, Sherman Hotel

2:00 P.M. A.W.S. Controls, Standards; Ballroom, Sherman Hotel

2:00 P.M. A.W.S. Machine Welding; Crystal Room, Sherman Hotel

2:00 P.M. A.I.M.E. Research in Progress; Tropical Room, Sheraton Hotel

2:00 P.M. A.I.M.E. Powder Metallurgy; Boulevard Room, Sheraton Hotel

Wednesday's Program, Continued

2:00 P.M. S.N.D.T. Technical Session; Morrison Hotel

4:30 P.M. A.W.S. Lecture: Nickel; Louis XVI Room, Sherman Hotel

5:00 P.M. ⊖ First Lecture: Titanium; Ballroom, Palmer House

6:30 P.M. A.W.S. Section and National Officers Dinner; Louis XVI Room, Sherman Hotel

6:30 P.M. A.W.S. University Research Dinner; Jade Room, Sherman Hotel

7:30 P.M. A.W.S. University Research Conference; Crystal Room, Sherman Hotel

7:30 P.M. A.W.S. Business Meeting; Louis XVI Room, Sherman Hotel

8:00 P.M. S.N.D.T. Symposium: Ultrasonics; Morrison Hotel

8:00 P.M. ⊖ Second Lecture: Titanium; Ballroom, Palmer House

9:00 P.M. ⊖ Third Lecture: Titanium; Ballroom, Palmer House

Thursday, October 26, 1950

Exposition Open 10:00 A.M. to 6:00 P.M.

9:30 A.M. ⊖ Business Forum; Red Lacquer Room, Palmer House

9:30 A.M. ⊖ Fracture; Ballroom, Palmer House

9:30 A.M. ⊖ Constitution of Alloys; Room 14, Palmer House

9:30 A.M. A.W.S. Nonferrous Metals; Louis XVI Room, Sherman Hotel

9:30 A.M. A.W.S. Pressure Vessels; Ballroom, Sherman Hotel

9:30 A.M. A.W.S. Aircraft; Crystal Room, Sherman Hotel

9:30 A.M. S.N.D.T. Technical Session; Morrison Hotel

9:30 A.M. Special Libraries Association, Metals Group: Classification, Indexing and Punched-Card Filing; Illinois Institute of Technology

12:30 P.M. A.W.S. Board of Directors Luncheon; Jade Room, Sherman Hotel

1:00 P.M. A.W.S. Inspection Trip

2:00 P.M. ⊖ High Production Management; Saddle and Sirloin Club, International Amphitheatre

2:00 P.M. ⊖ Fracture; Ballroom, Palmer House

2:00 P.M. S.N.D.T. Mehl Lecture; Morrison Hotel

3:00 P.M. S.N.D.T. Annual Business Meeting; Morrison Hotel

7:00 P.M. ⊖ Annual Banquet; Ballroom, Palmer House

Friday, October 27, 1950

Exposition Open 10:00 A.M. to 6:00 P.M.

9:30 A.M. ⊖ Plasticity; Ballroom, Palmer House

9:30 A.M. ⊖ Physical Metallurgy; Room 14, Palmer House

9:30 A.M. A.W.S. Inert-Gas Metal-Arc Welding; Ballroom, Sherman Hotel

9:30 A.M. A.W.S. Oxygen Cutting; Crystal Room, Sherman Hotel

9:30 A.M. A.W.S. Locomotives and Railroads; Louis XVI Room, Sherman Hotel

6:00 P.M. 32nd National Metal Congress and Exposition ends

Details of Program

Saturday, Oct. 21

9:30 A. M. and 2:00 P. M.—Seminar on Atom Movements

NORMANDIE LOUNGE, STEVENS HOTEL

Formal Basis of Diffusion Theory, by L. Darken, U. S. Steel Corp., Research Laboratories.

Chemical Techniques and Analysis of Diffusion Data, by Cyril Wells, Carnegie Institute of Technology.

Tracer and Other Techniques, by R. Hoffman, General Electric Co., Research Laboratory.

Mechanisms of Diffusion, by H. Huntington, Rensselaer Polytechnic Institute.

Diffusion in Two-Component Systems, by J. Bardeen, Bell Telephone Laboratories.

Analysis of Bulk Diffusion Data, by C. E. Birchenall, Carnegie Institute of Technology.

Sunday, Oct. 22

9:30 A. M. and 2:00 P. M.—Seminar on Atom Movements

BALLROOM, PALMER HOUSE

Surface and Boundary Diffusion, by D. Turnbull, General Electric Co., Research Laboratories.

Diffusion and High-Temperature Oxidation, by C. Wagner, Massachusetts Institute of Technology.

Gas-Metal Diffusion and Internal Oxidation, by F. N. Rhines, Carnegie Institute of Technology.

Diffusion in Sintering, by P. Duwez, California Institute of Technology.

Boundary Movements, by J. Burke, General Electric Co., Knolls Atomic Power Laboratory.

Summary and General Discussion.

8:00 P. M.—Sales Clinic

BALLROOM, PALMER HOUSE

Monday Morning, Oct. 23

Session on Surface Phenomena

BALLROOM, PALMER HOUSE

9:30 A. M.—**The Carbonitriding Process of Case Hardening Steel**, by G. W. P. Rengstorff, Battelle Memorial Institute, M. B. Bever and C. F. Floe, Massachusetts Institute of Technology.

10:00 A. M.—**Constitution of Carbonitrided Cases**, by G. W. P. Rengstorff, Battelle Memorial Institute, M. B. Bever and C. F. Floe, Mass. Institute of Technology.

10:30 A. M.—**Effect of Bath Composition on Aluminum Coatings on Steel**, by D. O. Gittings, D. H. Rowland and J. O. Mack, Carnegie-Illinois Steel Corp.

11:00 A. M.—**Formation of Oxides on Some Stainless Steels at High Temperatures**, by H. M. McCullough, Sylvania Electric Products Inc., and M. G. Fontana and F. H. Beck, Ohio State University.

11:30 A. M.—**Oxidation of Pure Iron**, by J. K. Stanley and Miss J. vonHoene, Westinghouse Laboratories, and R. T. Huntoon, Carnegie Institute of Technology.

Monday Afternoon, Oct. 23

Management Session on High Production

CLUB ROOM, INTERNATIONAL AMPHITHEATRE

Fabrication of Nonferrous Metals; Harvey A. Anderson, chairman, Engineer—Raw Materials, Western Electric.

Monday Afternoon and Evening (Cont.)

Session on Physical Metallurgy

BALLROOM, PALMER HOUSE

2:00 P. M.—**Recovery and Cold Working of 52S Commercial Aluminum Alloy**, by Gerard H. Boss, Metallurgy Division, Oak Ridge National Laboratory.

2:30 P. M.—**A Metallurgical Investigation of Silver Chloride**, by R. D. Moeller, F. W. Schonfeld, C. R. Tipton, Jr., and J. T. Waber, Los Alamos Laboratory.

3:00 P. M.—**Molybdenum Plating by Reduction of the Pentachloride Vapor**, by W. J. Childs, J. E. Cline, W. M. Kisner and J. Wulff, Mass. Institute of Technology.

3:30 P. M.—**Structure of Permanent Magnet Alloys**, by A. H. Geisler, General Electric Co.

High-Temperature Properties of Metals

BALLROOM, PALMER HOUSE

4:15 P. M.—**Creep**, by Earl R. Parker, Univ. of California.

4:45 P. M.—**Stress-Rupture Testing**, by N. J. Grant, Massachusetts Institute of Technology.

5:30 P. M.—**Fatigue Testing**, by H. J. Grover and Howard C. Cross, Battelle Memorial Institute.

8:00 P. M.—**Oxidation**, by Carl Wagner, Massachusetts Institute of Technology.

9:00 P. M.—**Service Experience**, by John J. B. Rutherford, Babcock and Wilcox Tube Co.

Tuesday Morning, Oct. 24

Session on High-Temperature Metallurgy

BALLROOM, PALMER HOUSE

9:30 A. M.—**Transformations in Ferritic Chromium Steels Between 1100 and 1500° F. (595 and 815° C.)**, by F. J. Shortsleeve and M. E. Nicholson, Standard Oil Co.

10:00 A. M.—**Hardening of High-Chromium Steels by Sigma Phase Formation**, by John J. Gilman, Crucible Steel Co. of America.

10:30 A. M.—**Nickel-Aluminum-Molybdenum Alloys for Service at Elevated Temperatures**, by H. V. Kinsey, Department of Mines and Technical Surveys, and M. T. Stewart, National Research Council, Canada.

11:00 A. M.—**Sigma Phase Formation in a Wrought Heat Resisting Steel**, by A. E. Bindari, Illinois Institute of Technology, P. K. Koh, Allegheny Ludlum Steel Corp., and Otto Zmeskal, Illinois Institute of Technology.

11:30 A. M.—**Long-Time Elevated-Temperature Test of Chromium-Molybdenum Steels**, by A. B. Wilder and J. O. Light, National Tube Co.

Tuesday Afternoon, Oct. 24

Management Session on High Production

CLUB ROOM, INTERNATIONAL AMPHITHEATRE

Forming of Metals, Hot or Cold; J. W. Armour, chairman, Manager of Manufacturing Research, International Harvester Co.

Session on High-Temperature Metallurgy

BALLROOM, PALMER HOUSE

2:00 P. M.—**Formation of Austenite in High-Chromium Stainless Steels**, by C. B. Post and W. S. Eberly, Carpenter Steel Co.

2:30 P. M.—**Influence of Austenitizing Time and Temperature on Austenite Grain Size of Steel**, by O. O. Miller, Research Laboratory, U. S. Steel Corp.

3:00 P. M.—**Carbide Precipitation in AISI Type 304 Stainless Steel—an Electron Microscope Study**, by E. M. Mahla and N. A. Nielsen, E. I. du Pont de Nemours.

3:30 P. M.—**Some Aspects of Graphitization in Steel**, by G. V. Smith, J. A. MacMillan and E. J. Dulis, Research Laboratory, U. S. Steel Corp.

Tuesday Afternoon and Evening (Cont.)

Interpretation of Tests and Correlation With Service

BALLROOM, PALMER HOUSE

4:15 P. M.—**Correlation of Laboratory Tests and Service Performance**, by M. F. Garwood, H. H. Zurburg, and M. A. Erickson, Chrysler Corp.

5:15 P. M.—**Wear Tests and Service Performance**, by J. T. Burwell, Massachusetts Institute of Technology.

8:00 P. M.—**Corrosion Tests vs. Service Performance**, by Frank LaQue, International Nickel Co.

9:00 P. M.—**Limitations of Mechanical Testing**, by M. Gensamer, Carnegie-Illinois Steel Corp.

Wednesday Morning, Oct. 25

A.S.M. Annual Meeting and Lecture

BALLROOM, PALMER HOUSE

9:30 A. M.—Annual Meeting of the Society.

10:00 A. M.—**Edward deMille Campbell Memorial Lecture**, by E. C. Smith, Chief Metallurgist, Republic Steel Corp.

Wednesday Afternoon, Oct. 25

Management Session on High Production

CLUB ROOM, INTERNATIONAL AMPHITHEATRE

The Cutting of Metals; A. H. d'Arcambal, chairman, Vice-President, Pratt & Whitney Division.

Session on Heat Treatment

BALLROOM, PALMER HOUSE

2:00 P. M.—**A Hardenability Test for Deep Hardening Steels**; Wm. Wilson, Jr., Armour Research Foundation.

2:30 P. M.—**An Examination of the Quenching Constant, H**, by D. J. Carney and A. J. Janulionis, Carnegie-Illinois Steel Corp.

3:00 P. M.—**The Tempering of Chromium Steels**, by R. W. Balluffi, Sylvania Electric Products, Morris Cohen and B. L. Averbach, Mass. Institute of Technology.

3:30 P. M.—**Austenite Transformation**, by Axel Hultgren, Royal Technical College, Stockholm, Sweden.

Metallurgy of Titanium

BALLROOM, PALMER HOUSE

5:00 P. M.—**Historical Development, Extractive Metallurgy, General Properties of the Metal of Commercial Grades**, by W. J. Kroll, Bureau of Mines.

8:00 P. M.—**Melting, Casting, Working, Fabrication, and Testing**, by W. L. Finlay, Remington Arms Co.

9:00 P. M.—**Alloys of Titanium**, by Robert Jaffee, Battelle Memorial Institute.

Thursday Morning, Oct. 26

9:30 A. M.—**Business Forum**

RED LACQUER ROOM, PALMER HOUSE

Session on Constitution of Alloys

ROOM 14, PALMER HOUSE

9:30 A. M.—**The Ternary System Chromium-Molybdenum-Iron**, by J. W. Putman, Massachusetts Institute of Technology, R. D. Potter, Univ. of California, and N. J. Grant, Massachusetts Institute of Technology.

10:00 A. M.—**The Ternary System Indium-Cadmium-Zinc**, by S. C. Carapella, Jr., and E. A. Peretti, University of Notre Dame.

10:30 A. M.—**The Determination of Solidus Temperatures in Magnesium Alloys by Dilatometric Measurements**, by Heinrich Adenstedt, Wright-Patterson Air Force Base, and Jay R. Burns, Dow Chemical Co.

11:00 A. M.—**Constitution and Mechanical Properties of Zirconium-Iron Alloys**, by E. T. Hayes, A. H. Roberson and W. L. O'Brien, Bureau of Mines, Albany, Ore.

Thursday Morning (Cont.)

Session on Fracture of Metals

BALLROOM, PALMER HOUSE

9:30 A. M.—**Grain and Grain Boundary Compositions: Mechanism of Temper Brittleness**, by J. W. Spretnak and Rudolph Speiser, Ohio State University.

10:00 A. M.—**Effect of Strain Rate on Toughness of Temper Brittle Steel**, by D. C. Buffum and L. D. Jaffe, Watertown Arsenal.

10:30 A. M.—**The Influence of Chromium on the Mechanical Properties of Plain Chromium Steels**, by W. O. Binder and Howard R. Spendelow, Jr., Union Carbide and Carbon Research Laboratories, Inc.

11:00 A. M.—**Rheotropic Embrittlement of Steel**, by E. J. Ripling and W. M. Baldwin, Jr., Case Institute of Technology.

11:30 A. M.—**Embrittlement of Stainless Steel by Steam in Heat Treating Atmospheres**, by C. A. Zapffe and R. L. Phebus, Research Metallurgists.

Thursday Afternoon, Oct. 26

Session on Production Management

CLUB ROOM, INTERNATIONAL AMPHITHEATRE

Management's Part in High Production, by Emil F. Gibian, Chief Industrial Engineer, Thompson Products, Inc.

Session on Fracture of Metals

BALLROOM, PALMER HOUSE

2:00 P. M.—**Fracturing of Silicon Ferrite Crystals**, by C. F. Tipper, Cambridge University, England, and M. Sullivan, Naval Research Laboratory.

2:30 P. M.—**A Study of Cleavage Surfaces in Ferrite**, by E. P. Klier, University of Maryland.

3:00 P. M.—**Fractographic Registrations of Fatigue**, by C. A. Zapffe and C. O. Worden, Research Metallurgists.

3:30 P. M.—**Effect of Alloying Elements on Notch Toughness of Pearlitic Steels**, by J. A. Rinebolt and W. J. Harris, Jr., Naval Research Laboratory.

Friday Morning, Oct. 27

Session on Plasticity

BALLROOM, PALMER HOUSE

9:30 A. M.—**The Stress-Strain Energy Relationship for Metals**, by D. J. McAdam, Jr., Consulting Metallurgist.

10:00 A. M.—**Tension-Compression Biaxial Plastic Stress-Strain Relations for Aluminum Alloys 24S-T and 2S-O**, by J. H. Faupel, E. I. du Pont de Nemours & Co., and Joseph Marin, Pennsylvania State College.

10:30 A. M.—**Hot Forming of Aluminum and Magnesium Alloys**, by T. E. Piper, Northrop Aircraft, Inc.

11:00 A. M.—**Strain Hardening of Mild Steel in the Torsion Test as a Function of Temperature**, by Hugh Larson, Massachusetts Institute of Technology, and E. P. Klier, University of Maryland.

Session on Physical Metallurgy

ROOM 14, PALMER HOUSE

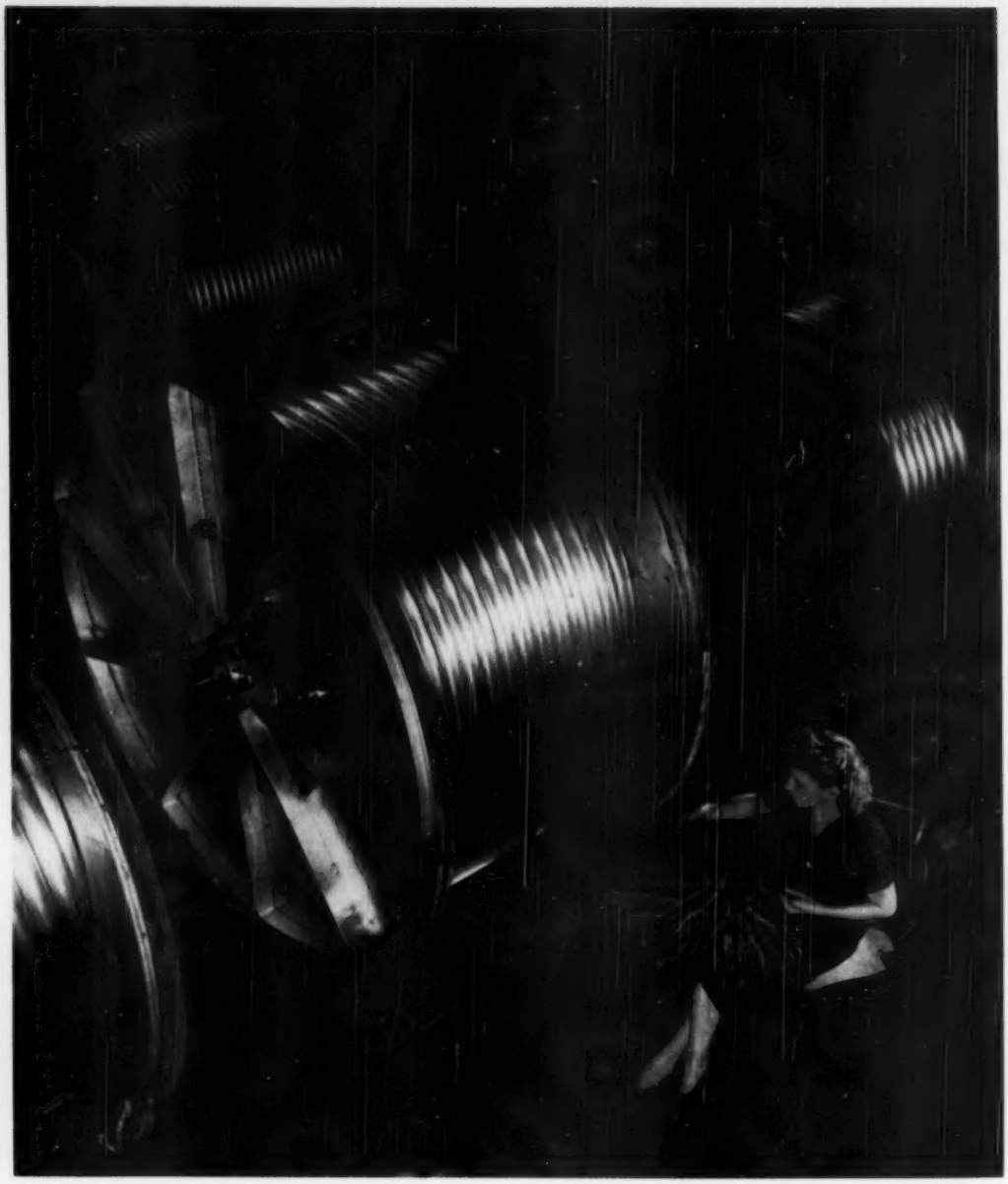
9:30 A. M.—**The Powder Metallurgy of Beryllium**, by H. H. Hausner & N. P. Pinto, Sylvania Electric Products.

10:00 A. M.—**The Dimensional Behavior of Invar**, by B. S. Lement, University of Notre Dame; B. L. Averbach and Morris Cohen, Mass. Institute of Technology.

10:30 A. M.—**Titanium-Chromium Binary Alloys**, by D. J. McPherson, Armour Research Foundation, and M. G. Fontana, Ohio State University.

11:00 A. M.—**Statistical Analysis of the Effect of Alloying Elements on Mechanical Properties of Seamless Steel Tubes**, by W. T. Rogers, National Tube Co.

11:30 A. M.—**Grindability of Tool Steels**, by L. P. Tarasov, Norton Co.



Plexus of Acoustic Nerve Fibers

Final inspection testing of toll telephone cable, for its electrical values, as photographed by Holmes I. Mettee at Point Breeze plant of Western Electric Co., shows it to be a work of intricate metallurgical nature. Hundreds of pairs of fine copper wires, adequately insulated each from each, and properly laid into a cable, the whole then tightly covered by a hardened lead sheath, which is extruded around the cable core by a unique process.

The 1940's have witnessed a fundamental change in American brass mills. Substitution of mechanical handling devices for expensive labor has resulted in faster work on bigger units and a better product.

Revolution in

Copper and Brass Mills

THE CHANGE now in progress in the copper and brass mills is so profound that one shrinks from estimating its depth or defining its limits. Yet, it is only a detail of an epoch in which zest for mechanization, having increased at a steadily accelerating rate for a long time, has attained a speed that is difficult fully to comprehend. Any effort to do so is not only dizzying but rather terrifying. Contemplating the effect of limitless mechanization on the mores, if not even the morals of humanity, fills the soul of one of the older generation with nostalgia, even trepidation. However, I doubt if any of them would wish to work again in an old-time brass mill!

While the evolution of the brass mill is a detail of the vastly broader general surge, it is essentially a struggle for survival. Perhaps that could be said of all industry and, more inclusively, of all evolution. It is part of the principle that requires living things to adapt themselves to their conditions or perish. As the 20th century wears on, it becomes increasingly apparent that the products of the brass mill cannot survive in a competitive sense unless they can be produced cheaply in terms of human labor.

The time is long past when the chief incentive to improvement of processes was to achieve a local advantage over a neighboring mill, with the result that such advantages were jealously guarded. Today, the goad to progress is the urgent necessity of keeping up with the procession as a condition of staying in business. Consequently brass mills now have comparatively few secrets from one another. They all buy their heavy equipment from common sources and, through the technical societies, discuss the technical aspects of metals. This is wholesome and beneficial. For, while American brass mills are in thumping competition with one another, they are more vitally, as an industry, in competition with aluminum, plastics, and stainless steel.

For many purposes copper and brass appear to be quite indispensable; for many others they are preferred. But all things are relative and preference is likely to be qualified by cost. By mechanization, the copper and brass industry has maintained itself. That will be the theme of the following remarks. But there is one important observation that must be made: As mechanization increases, the quality of the product steadily improves. The tradition of superior workmanship in the hand-made days is all very well, and has some solid foundations, but in countless applications mechanized processes not only do the work faster — they do it better!

It is doubtful if there have been any important developments in the brass mill during the last ten years that did not have their roots established

By Daniel R. Hull
Assistant Technical Manager
The American Brass Co.
Waterbury, Conn.

long ago, for the growth of a process requires time. We are here concerned with those that have recently grown to important practical dimensions.

Casting of Slabs for Flat Rolling

At the end of the 1930's the water cooled mold had, for a long time, been known and widely discussed. It was used in Europe but aroused little interest in America, for its advantages were not very obvious. Twenty years ago the castings for sheet and strip mills did not, in the main, much exceed 200 lb. in weight and were stocked in a complete range of widths by ¼-in. intervals, or less, from about 3½ to 16 or 18 in. In fact, the casting was made to order for finishing into the desired product with the least possible amount of edge scrap. It meant that from five to ten molds were required for each furnace charge, and that the molds were constantly being shifted. Under such conditions it was difficult to envision any advantage from water cooling.

Daniel R. Hull

His working life with The American Brass Co. in Waterbury has spanned the transition from small mills operated by artisans rich in ancient lore, brawny men who swung a 200-lb. piece dextrously, to large mechanized factories suggesting "a paradise of roller coasters, where coils appear to follow their devious courses of their own volition". Daniel Hull is one of the few survivors of Committee X, A.S.T.M., and his company and advice are sought by brass metallurgists everywhere. Uniquely, also, he can write the English language, as all who have read his "Casting of Brass and Bronze" will agree.

The impetus to change came in a manner that was not premeditated — namely, from the rolling mill. As far back as the early 1930's one sensed that something important was astir in the minds of a few of the more thoughtful rolling mill men. The potential advantage of heavier castings was the yeast at the bottom of it. More about this will come later, but heavier bars meant mechanical handling. That meant that a great number of exact casting widths no longer fitted the pattern. Castings would be made in only two or three widths, all of them wide by former standards, and desired strips would be slit after rolling. This meant molds of larger capacity, one or two of which would hold an Ajax furnace charge. The cast iron slab molds that had served so long and well were not adapted to this situation, but the water cooled mold, installed in a permanent station, fitted it admirably.

Old objections to water cooled molds then disappeared and they came in, during the early 1940's, like a flood. They came barely in time, for without them it is difficult to imagine how the brass rolling mills could have performed the service that, in the succeeding years, they did.

Extrusion Billets

In making billets to be extruded into rods or tubes, the increase in size of casting was not so great, but it was significant. By the end of the 1930's, the extruders of the brass industry were getting old, and few of them used billets larger than 6 or 7-in. diameter. A flush of new machinery of greatly increased capacity was probably influenced by the enormous needs of aluminum, but the brass business was also affected. Large extruders were often able to take billets of 8 and 10-in. diameter; this approximately doubled the size of the casting. Here again, water cooled molds were indicated and again it was a change in mill equipment that invoked the change in casting. (Tube piercing, in its nature, precludes any probability of increase in size of the casting, since the pierced tube is somewhere near the same diameter as the billet.)

For melting, the Ajax-Wyatt furnace was, in 1940, so nearly universal in the brass mill that other furnaces scarcely mattered. From the original 60 kw. and 600 lb. it had increased variously to 100 or 120 kw. and 1000 to 1200-lb. capacity. Under the impetus of the next few years, one of the important questions was how to get the utmost from such a furnace. In many instances the power input was increased to 180 kw. and the capacity to 1500 or 2000 lb. In some instances double units were used with two inductor tubes serving one bath, while some of the brass mills built furnaces for 350 kw. with a capacity of 3500 to 5000 lb. Before the decade ended, an Ajax furnace of 1000-kw. capacity was in use and available.

Through it all there has been a trend, increasing in intensity, toward clear floors, lift-truck transportation, and direct movement of scrap from the mill to the casting floor, by-passing the metal storage. Part of the same movement is delivery of scrap to the furnace in bulk, and mechanical means of charging it. The overhead crane — the pride of the twentieth century's teens — is giving

place to the faster and more versatile lift truck.

The principle of continuous casting probably throws a longer shadow into the future than anything yet mentioned. Whether one thinks of a machine of the Rossi type, for large production, or a small specialized type for variety work, the 1940's were years of great developments.

The Rolling Mill

It has already been shown that all important changes in molds merely waited on the rolling mill's needs. This is where the great change started: It started with 4-high rolls and worked forward and backward.

With the old conventional stand, consisting of a pair of rolls, there were very definite limitations. Due to the inevitable "spring", even in the heaviest of them, the edge of a rolled strip was always measurably thinner than the center. While this was counteracted, in the finishing passes, by skillful grinding so as to roll "on a hump", it was tricky and expensive work and the results were only relative.

Another limitation was in the "pinch" that could be taken. In the first pass after annealing, a fair reduction could be obtained, but as work hardening increased, the reduction per pass decreased sharply so that in the run-down stages it was not economical to give more than a couple of passes, with a total reduction of, perhaps, 40% between anneals. The final gage was approached cautiously, with light passes and much sorting, gaging, and classifying. If the desired width was more than about 3 in. it was usually finished (or even ordered from the casting shop) in single strip.

In this long-accepted state of things, the 4-high roll offered the first glimmer of hope for an idea that long had been attractive.

The first 4-high rolls were actually introduced into the brass mills in the 1920's, but their acceptance was slow. Their early performance was not breathtaking for there were countless details to be adjusted. The early and middle 1930's were not years of expansion and a conservative industry does not turn somersaults toward a piece of machinery as expensive as a 4-high roll stand until it has proved itself. So it fell to the last decade to realize the possibilities in 4-high rolling.

It has been learned that copper and many of the brasses can be rolled almost indefinitely, in the run-down stages, and thrive upon it. Reductions of 15 or 20 B&S numbers can replace the old practice of four to six numbers between anneals; furthermore, accuracy of gage formerly undreamed of can be obtained from edge to center of wide strips.

The only unforeseen hazard was "directionality", that curious phenomenon in which the physical properties of a strip of metal are different in one direction than in another. The condition had been known for a long time, in the occasional "earing" of drawn cups, but never really understood. Now, when the usefulness of 4-high rolling was threatened, the research metallurgists went to work and soon came up with the answers and mapped out the procedures that banished the temporary nightmare.

The ability to finish wide strips of uniform gage meant that all narrower requirements could be slit from two or three standard bars of about 18 to 24 in. in width. As remarked above, that put an end to the infinity of widths from the casting shop — which, in turn, not only allowed, but required, heavier castings. Once the bar was heavier than about 200 lb., which could be handled by two men, and the idea of any manual juggling whatever was clearly outmoded, the only limit to size was mill equipment. Much of this, such as run-out space in the breakdown stages, at the overhauling machines and the annealing furnaces, as well as the size of coilers, blockers, and slitters, was originally designed for the use of smaller bars, but adaptations came rather rapidly. Up went the weight of the casting for cold rolling to 700 to 1200 lb. (The brass castings for hot rolling vary in different mills from 700 to 1000, 1500, 2000 or even 3000 lb.) Simultaneously the roll conveyer

In the Brass Mill the Induction Furnace Is So Nearly Universal That Other Furnaces Scarcely Matter

A Wartime View at Western Electric's Hawthorne Works, Showing a Unit Casting Gilding Metal for Bullet Jackets

made its appearance. The idea is said to have been borrowed from a brewery, but however that may have been, it worked! Soon a rolling mill began to suggest a paradise of roller coasters. Coils of metal now moved in orderly procession, without help of human hand, from station to station, with trips, stops, shunts, elevations and descents. One assumes that a human mind directs them, but they appear to follow their devious courses of their own volition.

When heavy castings had become an accomplished fact, the advantages of hot rolling could not be overlooked. While some mills break down all castings hot and some do not, it is generally to be observed that, as the weight of the casting increases above 1000 lb., hot rolling shows an increasing advantage. Since the casting adaptable for cold breakdown is not usually thicker than about 3 in., and its length is limited by practical considerations of mold design, the heaviest bars are likely to be intended for hot rolling, for they can be 5 to 10 in. thick. Consequently hot rolling has greatly increased in the last decade but, of course, there will always be alloys that are not suitable for it.

Mills devoted exclusively to cold rolling have developed autogenous arc welding in an inert atmosphere to join coils, when a very long coil is desired. The long coil is one of the postwar developments that fits into the rolling mill picture and is increasingly in demand.

In the last decade the Sendzimir mill has made its appearance in the brass mill. Its astonishing performance in taking heavy reductions and in accuracy of gage carries to further ranges the movement that was started by the simple 4-high mill.

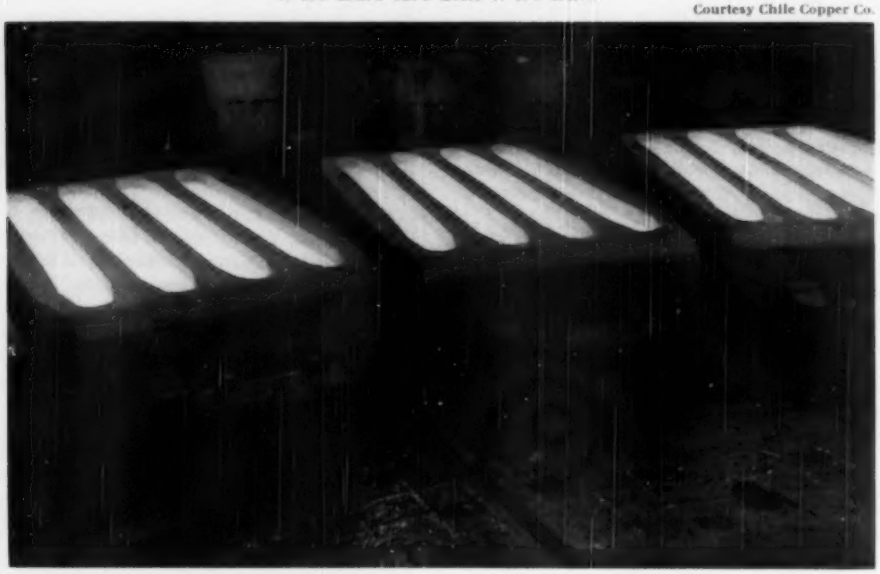
The gas-fired annealing furnace with atmosphere control was in the offing in 1930 and the doom of the oil-fired muffle was already written. But development takes time and, again, it was during the last decade that the change reached its full momentum. There are now few oil furnaces left in the brass mills. They had had an era of about 30 years — 1910 to 1940 — and no one mourned their passing. Annealing is cleaner and more accurate than it ever was before.

Also gone, for the most part, are the old-fashioned lead-lined pickle tubs, displaced by stainless steel creations of either "push through" or "pull through" type. They do better work and do it faster. Brass and copper do not get as many anneals as they used to, and what they get do not scale them as formerly, thanks to controlled atmosphere. Nevertheless, pickling is still a necessary process, but there isn't so much of it.

In this connection one remembers how, in former days, every young engineer who went to

Wire Bars Are Still Wire Bars

Courtesy Chile Copper Co.



work in a brass mill became enthused at the prospect of recovering copper from pickle. Time usually disillusioned him, not because the losses through pickling were unreal, but because recovery was vastly more complex and expensive than at first appeared to him, except in some particular circumstances. It is both gratifying and amusing to observe that in the 1940's the problem was perhaps three quarters eliminated by 4-high rolling mills and controlled atmosphere furnaces.

The Tube Mill

In tube manufacture the 1940's have also been epochal — not so much, perhaps, in the birth of new principles as in the revamping of mills and the extension of old principles.

Of course, the same change in annealing furnaces has occurred as in the sheet and strip rolling mill and all other departments. Cored shell castings have almost disappeared from the tube mill and the cupping of disks to make condenser tubes has not been heard of for a long time. While copper tubes have been pierced for many years, the practice has been extended to such alloys as are suited. Most of the alloys not suitable for piercing can be extruded, and while the process dates from an earlier period, extrusion really came into its own during the last decade. New and powerful equipment for both piercing and extrusion has been widely installed.

The old, slow, short, single-strand drawbench has been superseded by swift and powerful benches drawing two or three tubes simultaneously in lengths of 100 or 150 ft. The phenomenal increase in the use of copper water tubes has inspired one of the most unique developments of the decade — the floating plug which permits the drawing of tubes on a drum, in coils.

Rod and Wire Mills

Rod and wire mills have not seen such fundamental changes as other departments. Progress in the last decade has mostly been evidenced by improved designs for familiar machines. More powerful extruders have enabled the mills to use billets 8 or 10 in. in diameter, where 6 or 7 in. was formerly the average. Multiple-stand rolls in tandem have been brought to a high degree of efficiency and some ingenious combination machines for drawing, straightening, and cutting-to-length have been devised. These both date back quite a long way, but during the last ten years they have been improved and have come into much more general use than formerly. A most interesting recent development is the resistance annealing of wire as it emerges from a multiple-die drawing machine, so that the product wound on the spool is already annealed and cold.

One advance is looming on the horizon — the use of back traction in a single die. The idea has gone through long discussion and laboratory development. Similar to the single-stand rolling mill with power-driven take-up reels and braked payoff reels, the wire would be under enough tension so it would be elongated correctly as it enters the die, leaving the latter the sole duty of giving correct shape and finish. A power saving and a better finish is in prospect.

The Future

The copper and brass mill makes no apology for not resembling a steel mill or an aluminum mill. The relative amount of the metallic elements in the earth set the course that mortal man cannot alter. The volume of copper and its alloys will always be smaller than iron or aluminum, but will serve purposes for which the baser metals are ill suited.

The copper and brass mills must maintain some 200 or 300 alloys. The size of the average order is small; the combinations of width, thickness, hardness and softness are legion. The mill is committed to almost infinite detail.

Yet, for all this, streamlined mechanization is the price of salvation. The immediate future will see the process accelerated, for we do not wish to imply that a peak or even a plateau of accomplishment has been reached. If copper and brass were as expensive in terms of man-hours as in the good old days, they would be too much of a luxury for common consumption.

The details in which labor saving will be manifest are not so easy to forecast and one becomes shy of the prophet's role. A few things, however, can be seen. One would guess that there will be more continuous casting. For the common alloys the size of the mill unit will continue to increase. There will be more Ajax furnaces of 1000-kw. capacity. Strand annealing of strip may be expected to develop. The multiple-roll arrangement for rolling mills, as in the Sendzimir and 4-high, appears to have a great future. The electronic gage, automatically adjusting the rolls, is in sight. The thousand and one mechanical adjuncts that machine builders will devise and brass men will adopt are in the lap of the future.

But this is the direction in which the copper and brass mills are headed and in which they must travel.

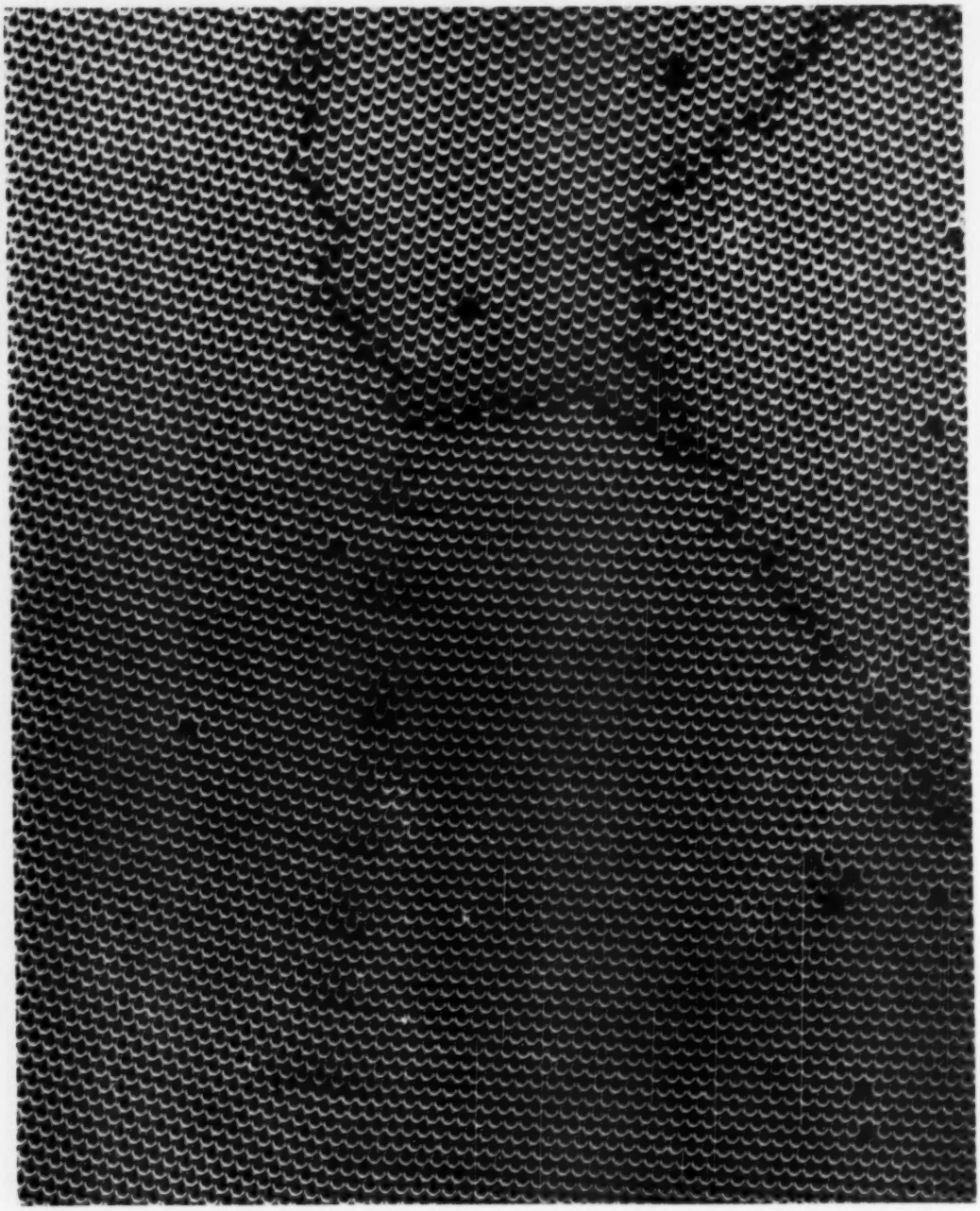


Fig. 1 — Array of Soap Bubbles, Simulating Atomic Planes in Crystal Lattices, Showing Continuous Dislocations Between Disoriented Grains, Noncontinuous Dislocations Between Grains More Nearly Oriented, and Missing Atoms Within the Crystal Itself

Progress in such a practical thing as a better metal for high-temperature service will be on a cut-and-try basis until enough is known about the forces that hold atoms together. This is the prime problem studied by metal scientists, and a healthy beginning has been made in America since 1940.

A Decade of Metallurgical Science

THE COMPLETE DISRUPTION of the normal path of development caused by World War II fortunately did not have a deleterious effect on the growth of American metallurgical science. Partly because events emphasized the spectacular values that can be derived from scientific research, and partly because in disturbed conditions new ideas are more apt to be nucleated and new experiments more readily tried, the result really was an infusion of new life into the metallurgical scene. This more general appreciation of fundamental research has enabled an increased number of "pure scientists" to work on metallurgical subjects, and has removed the professional objections to such "impractical activities" as the study of metals. Fewer metallurgists are now content when they know "what" and are asking "how?"

For many years work of a really fundamental nature in the field of metallurgy was an unwanted stepchild, supported neither by metallurgists nor by physicists. Now, however, the intelligent programs of the Office of Naval Research and the Atomic Energy Commission in supporting fundamental work have made it unnecessary for a scientist to demonstrate an immediate practical utility for a proposed investigation, and many metal producing and using concerns are adopting a long-range view of research, and are supporting in their own laboratories and in universities extensive research aimed only at gaining knowledge.

However, it must not be forgotten that metallurgy is still a compound of much art and relatively little science, and that its advance cannot depend on scientific progress alone. The practical man's problems and his contributions to their solution are no less numerous than before, and the problem of liaison between science and practice is more acute.

All in all, it is the writer's belief that the most important difference between the last decade of metallurgical science and the one that preceded it has been the much closer association of metallurgists with physicists and physical chemists. The problems we were concerned with in 1940 are still with us in 1950, and largely unsolved; however, they are better defined and one has some grounds for confidence that their solutions are imminent.

Dislocations—in 1940 not much more than a vague concept to the average metallurgist—have become basic to the thinking of any physical metallurgist today, although the extent to which precise mathematical treatment of the subject is possible is still small. The striking appearance of the Bragg model composed of tiny soap bubbles which aggregate into crystal rafts, shown on the page opposite, has done much to make the *idea* of dislocations acceptable to metallurgists. Properties and behavior of metallic crystals have been calculated on the basis that the atomic architecture is not absolutely regular but contains many irregularities (dislocations). Many such calculations, made both in England and the United States, have generally seemed too idealized to be

By Cyril Stanley Smith
Director, Institute for the Study of Metals
The University of Chicago

significant to a practicing metallurgist, however much he may be in agreement with the qualitative concept. There is a great need for some simple experiments in which the properties of dislocations can be uniquely associated with some measurable effect. (Incidentally the bubble model was suggested in 1926 by Ernest E. Thum,* editor of *Metal Progress*.)

In the meantime all metallurgists will continue to use the concepts qualitatively to account for the weakness of any real crystal and to help to explain the mechanism of slip, creep, and other aspects of plastic deformation. The yield point phenomenon and associated strain-aging effects are easily understood in terms of the segregation of carbon and nitrogen atoms to the vicinity of dislocations, and their effect on dislocation motion at varying speeds and temperatures. The structure and properties of a grain boundary become properly understandable in terms of arrays of dislocations, particularly between grains differing little in orientation. Under conditions of slight disorientation, parts of crystals may have boundaries of dislocations far enough apart for their effects on local etching to be microscopically resolved and, though dislocations have neither been seen nor their actual existence otherwise proved unmistakably, it is a rare physical metallurgist indeed who does not now believe in and utilize the dislocation concept almost daily in his work.

Cyril Stanley Smith

In his early association with American Brass Co. he was "armored with the awareness that dogma and assertion do not constitute proof", in the words of one of his associates. In his wartime work at Los Alamos, where he had charge of the metallurgical end of designing and building the atomic bomb (and for which he received the civilian Distinguished Service Medal) he was able to "think like, talk to, and understand the problems of the physicists". This is the man who is now heading the most ambitious search into metal science existing today in America.

Recovery and Recrystallization

French and English work showing the presence of low-energy boundaries between parts of crystals differing very slightly in orientation, the relation of these to veining (with which the metallographer has been familiar for many years), and the demonstration that these can be intentionally produced under certain conditions of straining and annealing has made the phenomena of recovery and nucleation of recrystallization intelligible. The structure of cold worked metals, though frequently studied, has not been greatly elucidated; beyond certain rather vague concepts, the reason for increased hardness after deformation is only qualitatively explicable. Nevertheless, X-ray techniques have been refined to a point where average distortions on an atomic basis can be precisely determined from an examination of X-ray scattering over wide angles, and the concept of faults (stacking errors; one-layer twins) as an additional mode of deformation has been introduced and conclusively demonstrated.

In the absence of an accurate picture of the detailed mechanism of deformation it is not surprising that preferred orientation is without a precise explanation. Our knowledge of preferred orientation in annealed materials is in better shape, for it is now known that the rate of movement of a grain boundary of a recrystallizing material is strongly dependent on the relative orientation of the new and the old grains.

In the 1920's, work on grain growth had reached a stage of development where future study promised diminishing returns. Though great strides were then made in the practical control of grain size of commercial products, scientifically the field lay dormant until in the last decade it again burgeoned with activity.

As a result of this study it is now known definitely that the driving force for grain growth is the energy associated with grain boundaries, and is a surface-property, not a volume-property. The boundaries establish local equilibrium at an angle of 120°, and the reconciliation of these angles with the random contacts between grains introduces curvatures. Since each boundary tends to move toward its center of curvature, the network of boundaries seeks equilibrium but never reaches it until the process finally stops, either because inclusions prevent further displacement, because slight variations of grain boundary energy with grain boundary orientation inhibit further motion,

*EDITOR'S SHY FOOTNOTE — Discovered on the kitchen stove, as I recollect it, in a dishpan half full of slightly soapy water, the bubbles rising from a dish mop just above a small gas flame.

or because the grains have become commensurate in size with the whole specimen.

A polycrystalline metal is a network of surfaces between grains and phases, and the microstructure of an annealed alloy results from the attempts of these surfaces to reach the equilibrium outlined above. In an alloy containing more than one phase the angles at which the interfaces meet will be determined by surface tension equilibrium — like a drop of oil on water. However, the surfaces phase to phase are different and have different energies than in a single-phase metal, and the boundary angles will not necessarily be 120°. Though a particle of a second phase entirely within a single grain will tend to be spherical, such a phase in contact with grain boundaries of another will be angular, the angle becoming more acute as the energy of its interface with the main crystal decreases (reaching zero if this energy is half or less that of the grain boundary energy).

This rather simple concept, ignoring variation of interface energy with the relative orientation of the two crystals meeting at the interface, explains the microstructure of most annealed alloys, though it needs considerable extension for oriented precipitates and other structures in which the surface energy is low because of close matching between crystal lattices. These are very important exceptions but they do not constitute the most common behavior.

Nucleation — Surface energy is equally important in another field that has recently received a good deal of attention — that of nucleation. The critical size of a nucleus of a solid phase that will grow in a matrix of liquid depends on the balance between the free energy of transformation (which drives the reaction and which is volume-dependent) and the area-dependent surface energy which tends to retard the reaction but which, being proportional to area, is less significant as the particle size increases. Solidification of metals in bulk is generally a result of foreign insoluble nuclei, but if these are removed, metals can undercool to an astonishing degree — as much as 400° C. in the case of platinum — before nucleation automatically occurs in the homogeneous liquid.*

Transformations in the solid state are equally dependent upon surface energy. However, in these phenomena the energy balance is complicated by the existence of strain energy due to coherency stresses between the old and new phases, and by the resulting high variation of total energy with the orientation of the precipitate due to both strictly crystallographic and elastic anisotropy. The transformations in steel, which metallurgists have studied so much in the past and are so important to technology, are extremely complex and difficult to unravel — fundamentally no less than practically. Research metallurgists have at last realized that they will advance the subject faster if they begin with the study of much simpler transformations — for example those from face-centered cubic to face-centered tetragonal lattices, where the only change is in axial ratio. In these the lattice relationships are closely analogous to twinning and there is some hope of understanding the strain system involved, for the picture is not complicated by diffusion and differences in composition. Particularly interesting in this connection are the indium-thallium solid solution with about 20% thallium (Fig. 2), and the "compound" AuCd. Neither of these is of any industrial importance, but they have already helped us understand the martensite transformation in steel.

Magnetic Materials

Many new magnetic materials have been developed — including vastly better permanent magnets made by controlling the nucleation of a precipitate of a magnetic material during cooling. Particularly interesting has been the work of an

Fig. 2 — Lamellar Microstructure Produced in Indium-Thallium Alloy (20.7 Atomic % Thallium) by Transformation From Face-Centered Cubic to Face-Centered Tetragonal Structure — the Simplest Possible "Martensite" Transformation. 100×

*Editor's Query — Is the "blick" of a gold button so strikingly observed in the fire assay the recalescence of an undercooled single-phase alloy? (The gold-silver button has an extraordinary degree of purity.)

industrial laboratory where the formation and movement of domain boundaries in a magnetic field was observed through a magnetic colloid spread on large crystals of silicon ferrite, confirming in a most striking way the correctness of the theory. Powders of pure iron or nickel, of sufficiently small particle size to be a single domain, make excellent permanent magnet materials. Valuable information on the domain boundaries and on the structure of metals has been derived from studying the interaction between magnetic domain boundaries and precipitates, strains, or even fluctuation of concentration in solid solutions. Polarized beams of neutrons from a nuclear reactor have uncovered further information on domains; diffraction of neutrons has proved particularly important in showing anti-ferromagnetic order in such materials as manganese and its fluoride, where electron spins interact in anti-parallel positions. Neutron diffraction will prove an important tool in studying such structures in other metals, as well as for simple diffraction studies on crystals containing hydrogen or carbon which are difficult to find by X-ray methods.

Research on nonmetals has helped the formulation of concepts of great use to the metallurgist. Work initiated on semiconductors for wartime radar has placed the theory of electron energy levels on a very firm foundation. Studies on ionic crystals, in which lattice vacancies can be produced either at high temperatures or by the substitution of a cation or anion of different valence, show unmistakably the significance of vacancies in the phenomena of diffusion, and that two kinds of atoms do not necessarily diffuse at the same rate in a given material. Nevertheless, it is an open question whether, in a typical close-packed metal, *vacancies* are a primary mechanism for interchange of atom position in diffusion. Despite the large amount of study, stimulated by the work at Carnegie Institute of Technology, the recent data have tended to expose inadequacies rather than to consolidate the theory of diffusion. Grain boundary diffusion is clearly of much greater importance than heretofore suspected. Particularly important is the discovery of the large mechanical effects (distortions and local volume changes) accompanying diffusion in solid solutions. First discovered in brass, this effect has been detected in many other systems and found to be of considerable practical importance, both in alloy powder metallurgy and in the production of internal defects during the homogenization of alloy castings.

In experimental techniques the 1940-1950 decade has been marked by steady progress rather than by spectacular new methods. In the X-ray diffraction field, the application of Fourier analysis has given much detailed information on distribution of atoms that exist in advance of precipitation or ordering. Methods of small-angle scattering and high-resolution Laue techniques are applicable to studies of pre-precipitation segregation, and to subgrain structures respectively. Perhaps no change is more important than the development of automatically recording X-ray diffraction spectrometers; patterns can be obtained with them in far less time than heretofore; they are even speedy enough to allow the experimenter to follow a transformation continuously.

A decade ago internal friction of metals was being measured in one or two laboratories throughout the world, partly for its supposed engineering value and partly out of sheer scientific curiosity. (Such energy absorption is easily measured with a torsion pendulum apparatus of great simplicity.) Since then its use as a means of studying the structure and behavior of metals has matured. The acoustic spectrum of a metal — that is to say, the absorption of energy of a stress-strain cycle when plotted as a function of frequency — has a series of peaks, each corresponding to a definite atomic process. These may be associated with the relaxation of stresses resulting from thermal inhomogeneities (either micro-size or macro), from the alignment of either substitutional or interstitial solid solution atoms in a direction to minimize stress, from the motion of twin boundaries (particularly in tetragonal crystals), or from stress relaxation across boundaries.

As an example of the utility of the method, it has recently been shown that the interstitial diffusion of carbon in alpha iron occurs by the same mechanism and at the same rate except for the acceleration due to temperature. This is true over the range from −50° C., where one atom jumps every few hours, to +900° C., where diffusion millimeters deep occurs in the same time. The absorption of energy by the sliding of one grain against another has also been measured by internal friction and correlated with factors uncovered by ordinary creep experiments. The old amorphous metal hypothesis — enunciated 40 years ago by Rosenhain — has been revived.

Two techniques which 10 years ago seemed to hold great promise have not paid off, although very useful work has been done with them. These are the electron microscope and radioactive tracers. Though the latter agency is very useful in studying the transfer of material by wear and corrosion, and the reaction rates in refining processes, and has enabled work on self-diffusion to be done for the first time, being particularly important in studying grain boundary diffusion, it has not yet

extended in other ways the range of metallurgical experimentation. Though auto-radiographs have shown segregation, they have as yet uncovered nothing not previously known. This is in sharp contrast with tracer work in the biological field and, though the reactions of a metal crystal are quite different in nature from those of an organic molecule, this may indicate lack of imagination on the part of metallurgists.

The electron microscope has taken an important place beside the optical microscope, but its discoveries have essentially been only those predictable beforehand. The refinements of X-ray technique which enable it to study aggregation of atoms at very early stages of precipitation, and the methods of studying slight orientation changes, have proved far more important than the electron microscope. Should the resolving power of the electron microscope, and of the replicas that must be used with it, be increased by a factor of ten, its value would be enormous.

Professional Relations

The discussion above has dealt mainly with studies in which the physicist and the metallurgist associate with each other. The bond between chemists and metallurgists has been less apparent than in previous generations, although for most of history, chemistry has been the route through which advancing science has influenced the practical metallurgist. Cooperation is now reviving; chemistry promises to compete with physics in the forefront of metallurgical thinking.

For example, the past decade has seen increased interest in the field of metallic solutions. This has led to greater mutual understanding, first on the part of metallurgists of the principles and possibilities of chemical thermodynamics, and, second, on the part of chemists of important fields within the chemistry of metals. Metallurgical thermodynamics is proceeding at a fast rate from the era of the phase rule to the era of chemical potential, activity, and entropy. Research metallurgists are beginning to use statistical mechanics to infuse real meaning to thermodynamic quantities; they are now commonly studying metallic solutions, whether solid or liquid, by the classical techniques of equilibrium measurement in physical chemistry. Of these the most important are the vapor pressure method, the electrochemical method, and the method of heterogeneous equilibrium. Each with its special limitations and advantages for particular systems will permit the activity of a given element to be followed throughout a series of alloys, and give information about the interaction of atoms in a precise form previously only guessed at from the shape of the constitution diagram. When this general point of view is wedded with the concepts of crystal chemistry and zone theory, the phase diagram will be completely predictable.

Future Trends

There is reason to be pleased at the progress in the science of metals over the last decade. Nevertheless, the scientist must not feel that he is indispensable to progress. One must admit that recent notable improvements in materials for withstanding high temperatures were made by cut-and-try extension of previously acquired ideas, and have not been matched by any equivalent increase in understanding of the fundamentals of stress resistance at high temperatures. The famous ship-plate studies did not appreciably benefit from scientific knowledge, and in turn did not perceptibly advance knowledge of the mechanism of fracture. Other important technological developments like continuous casting, precision casting, ceramets, titanium metallurgy, and even plutonium metallurgy, have all occurred without any stimulus from fundamental science.

A problem of vast industrial importance is that of corrosion. This reviewer sincerely hopes that he is wrong in predicting that there will be no significant advance made in the theoretical understanding of this subject in the next decade, though some meaningful experiments will certainly be performed (particularly in analyzing corrosion current circuits), and improved materials will be developed.

One can, nevertheless, confidently predict for the future that metallurgists will more and more appreciate the role that science can play in the development of metallurgy, and that the physics of solids will flourish as a science as a result of the closer contact being established between metallurgists and physicists.

One may anticipate three important advances in the next decade: First, the development of the theory of dislocations (in close association with experiment) to the point where it can predict rather than merely explain, and with this will come fuller understanding of deformation and work hardening. Second, the fruition of the theory of the crystal structure of alloys; the present rules, though intriguing and important, have so many exceptions as to be without practical value. Finally, the advances in chemical thermodynamics and in statistical mechanics will be utilized by metallurgists of all kinds — those concerned with alloying, fabrication, and utilization, as well as the smelter and refiner of metals.

"High production" is an old story for the aluminum industry. It engineered a four-fold expansion during the war, and is currently producing ingot at four times the 1939 rate. The industry is also prolific in "tailor-made" alloys — a matter reviewed in this contribution.

Aluminum Alloys—1940 to 1950

THE ALUMINUM INDUSTRY during the first half of the past decade had but one objective — to meet America's tremendously expanded military requirements. How well it met this challenge is a glorious history. Utilization of the greatly enlarged capacity in the postwar years was another challenge. It too was successfully met. This brief article will discuss primarily the aluminum alloys prominent in these two periods.

The war in the air was fought and won largely with the alloys available at the beginning of the war. Approximately 90% of the aluminum used in the war effort of the United States went into aircraft. About 75% of the weight of a warplane was aluminum; of this weight, 48% was sheet, 13% extruded shapes, 11% forgings, and 7% sand castings.

Aluminum Alloys for Aircraft

Sheet — The principal sheet alloy was 24S,* a duralumin-type alloy of higher magnesium content and greater strength than the duralumin used late in World War I. This alloy was formerly considered very difficult to fabricate into sheet, yet during the last war it was readily rolled at high production rates. One of the three large sheet mills turned out monthly one and a half times as much high-strength alloy sheet as the whole nation had used in a year before the war. This was an amazing accomplishment.

Rivets — Most rivets used in aircraft structures were A17S-T3 alloy because these rivets are readily driven without reheat treatment. Some 17S and 24S rivets were employed, but the 17S rivets (usually) and the 24S (always) were driven in the freshly quenched temper, maintained by refrigeration after heat treatment.

Extrusions — The principal high-strength alloy for extrusions was 24S. Its extrusion rate was low, and in spite of the greatly increased extrusion capacities, Alcoa-operated plants having a capacity ten times the prewar level, some delays were encountered. Manufacturers were urged to substitute 14S alloy, because of its higher extrusion rate, but only limited conversion was made. The aircraft manufacturer got what he wanted.

Forgings — The use of strong alloy forgings in aircraft construction increased more than that of any other aluminum product. Alcoa's capacity was increased more than 25 times and other large forge shops were devoted to their manufacture. Alloy 14S, developed somewhat earlier than 24S, became the principal alloy for high-strength airframe fittings and for many power plant parts, including such difficult forgings as crankcases. The much more forgeable alloy A51S was also used where its lower strength permitted.

During the early stages of the war, aircraft

*The nominal composition of typical alloys is given in tables for convenient reference but no attempt has been made to give a complete listing.

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propellers were made from 25S, which was previously standard for this part. However, the so-called hard alloy 76S, an aluminum-zinc-magnesium alloy, soon began to supplant it for newer designs, in spite of the fact that many more blows were required in forging.

Table I — Composition of High-Strength Wrought Alloys

Alloy	Cu	Mn	Mg	Zinc	Others
14S	4.4	0.8	0.4		0.8 Si
17S	4.0	0.5	0.5		
A17S	2.5		0.3		
24S	4.5	0.6	1.5		
25S	4.5	0.8			0.8 Si
75S	1.6		2.5	5.6	0.3 Cr
76S	0.6	0.5	1.5	7.6	

The majority of forged pistons and cylinder heads for air-cooled aircraft engines were made of one of the several modifications of the original "Y" alloy developed in World War I. Of these, 18S and its free machining companion A18S were more readily forged than the higher magnesium modification B18S, yet the latter alloy was used to an increasing extent. Some pistons were made of Alcoa 32S alloy.

Castings — Cast aluminum cylinder heads for aircraft engines were produced in huge quantities and at record speed. These difficult castings with

Table II — Composition of Wrought Alloys for Elevated Temperature Service

Alloy	Cu	Mg	Ni	Pb	Others
18S	4.0	0.6	2.0		
A18S	4.0	0.6	2.0	0.4	0.4 Bi
B18S	4.0	1.5	2.0		
32S	0.9	1.1	0.9		12.2 Si

deep thin fins had to be of great soundness and uniformity. They were of the "Y" alloy type designated alloy 142 although some were made of 122 alloy.

Crankcases and other parts for liquid-cooled aircraft engines were made of alloy 355 and were solution heat treated and artificially aged. Another alloy of British origin RR50 (Cu 1.5, Si 2.3, Ni 1.3, Mg 0.15%) was used for parts of one liquid-cooled engine. It does not require a solution heat treatment; hence, many of the distortion difficulties were avoided. It was, however, artificially aged to increase the strength.

For aircraft landing wheels, alloy 195 for sand castings and B195 for permanent mold castings were used extensively in the early part of the war, and later alloy 356.

To relieve the tight forging situation in the early stages of the war, high-strength aluminum

Table III — Composition of Casting Alloys

Alloy	Cu	Si	Fe	Mg	Others
43		5.0			
122	10.0		1.0	0.2	
D132	3.5	9.0		0.8	0.8 Ni
142	4.0			1.5	2.0 Ni
195	4.5	0.8			
B195	4.5	2.5			
214				3.8	
220				10.0	
319	3.5	6.3			
355	1.3	5.0		0.5	
356		7.0		0.3	
A612	0.5			0.7	6.5 Zn
C612	0.5		1.0	0.4	6.5 Zn

alloy castings were used for many structural fittings. Radiographic inspection was used extensively, the more critical fittings receiving 100% inspection. The heat-treatable alloys 195 and 220 were used principally.

Rapid Analytic Methods — Spectrographic analysis of aluminum alloys, pioneered by Alcoa, had been perfected and its extensive use markedly reduced the personnel required for analyzing the huge quantities of metal produced for the war effort. The later development of direct reading electronic spectrometers makes analyses so quickly that the composition of the bath is determined before pouring, thus greatly minimizing the number of off-composition casts.

Developments in Aluminum Metallurgy

The fact that the alloys principally used for the warplanes were those previously available does not mean that new alloys and metallurgical practices were not developed during the war years. The contrary was true. Extensive research by private industry and sponsored by the government made major advances and the new developments were being incorporated in the newer military designs.

Acceptance of Artificially Aged Alloys — Probably the most important single development of the war years was the acceptance by the aircraft industry of artifically aged wrought aluminum alloys for structural members. This was a major change in aircraft engineering philosophy. Artificially aged

alloys had been frowned upon since their resistance to corrosion was uncertain. Engineers were also reluctant to rely on products having the high ratio of yield strength to tensile strength and relatively low elongation characteristic of the artificially aged products. This combination spelled "brittleness" to them.

The increasing and successful structural use of 14S-T6 forgings (solution heat treated and artificially aged) was undoubtedly an important factor in the change in attitude. Several aircraft companies on the West Coast almost simultaneously sponsored the use of artificially aged 24S. Although artificial aging of this alloy was largely limited to alclad sheet, it now has been established that with a well-selected aging treatment, the resistance to corrosion of even nonclad products is satisfactory. Indeed, with certain products of thick section which cannot be quenched fast enough to give maximum corrosion resistance, artificial aging improves their resistance to corrosion and stress corrosion. The transverse properties of thick extrusions are increased by artificial aging but strength is decreased in the longitudinal direction. Consequently, little use has been made of 24S aluminum alloy extrusions that have been artificially aged.

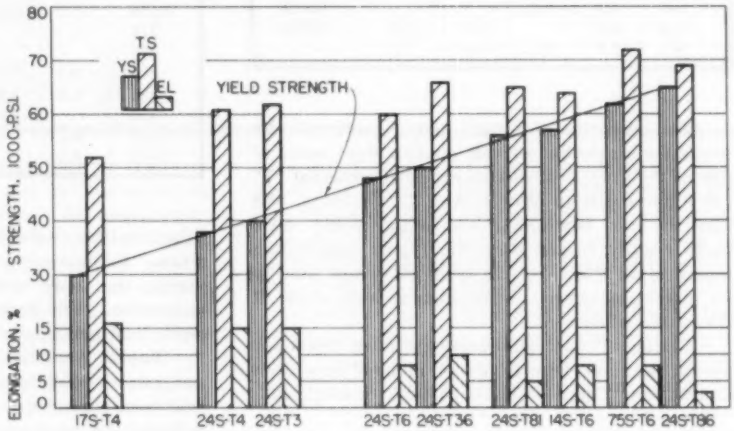


Fig. 1 — Tensile Properties (Specification Values for 0.064-In. Alclad Sheet) for High-Strength Aluminum Alloys

The New Aluminum-Zinc-Magnesium Alloy Alcoa 75S, after many years of research, was put into commercial production for alclad sheet and extrusions in 1943 and later for nonclad sheet, wire, rod and bar, and forgings. It requires artificial aging after solution heat treatment to achieve its final properties and has the characteristic high ratio of yield to tensile strength and a relatively low elongation, but its tensile yield strength is nearly 50% higher than that of the naturally aged 24S as used in the beginning of the war. (See Fig. 1.) By the end of the war most of the new designs of military aircraft were based on 75S-T6 and considerable quantities of this alloy had been used to lighten older models still in production.

Fatigue Strength of the New Products — Unfortunately, neither the new aluminum-zinc-magnesium alloy nor the other artificially aged products had an increased fatigue strength commensurate with their high static strength, particularly where notches existed — as is the case in most structural assemblies. Thus, greater consideration of the fatigue requirements of structures employing the higher strength materials is necessary.

High-Strength Alclad Sheet — Alclad sheet was used extensively in military airplanes, especially for those of the Army Air Forces. It avoided much protective painting and saved an enormous amount of manpower otherwise required for anodic treatments and painting. Modified quenching procedures were also feasible which minimized distortion of formed parts.

Reynolds Metals Co. introduced the sheet product R301 which consists essentially of a core of 14S alloy clad with a magnesium-silicide alloy, and also at one time offered an alloy of the aluminum-zinc-magnesium type designated R303.

High-Strength Alloys Summarized — In Fig. 1 and 2 the various alloy products have been spaced so that the bars representing the tensile yield strength fall on a slanting line. The wrought alloys, exclusive of forgings, which were available at the beginning of the war, include 24S-T3 and the alloys to its left (also 24S-T36) while those alloy products to the right of 24S-T3 were available more than a year before the war's end.

Other War Applications — Several other uses of aluminum, although not a part of the airplane, were directly related to aircraft activities. Some 45,000,000 lb. of landing mats of alloy 61S-T6 (see Table V) were used because the aluminum mats were half as heavy as the steel mats and could be

more readily flown into the new air strips. Light weight drums for transporting gasoline over the China-Burma-India route were also used. A 55-gal. drum weighed only 21 lb. when made of 61S-T4 aluminum alloy, 30 lb. less than those previously available.

High and Low-Temperature Applications— Jet engines have created an insistent demand for aluminum alloys of improved high-temperature properties, including fatigue and creep, but despite extensive research alloys are not yet available for efficient use at temperatures higher than 400 to 500° F. In this respect, a British alloy RR58 (Cu 2.2, Mg 1.6, Ni 1.1, Fe 1.1, Si <0.25%) is thought to be somewhat superior to the best available American alloys for high-temperature service, but so far has been used in this country in only one type of jet engine, which is of British design.

The picture for aluminum alloys for sub-zero uses is much brighter because these alloys experience no loss in mechanical properties at temperatures as low as that of liquid nitrogen, and for this reason they are being found eminently suitable for equipment operating at low temperatures.

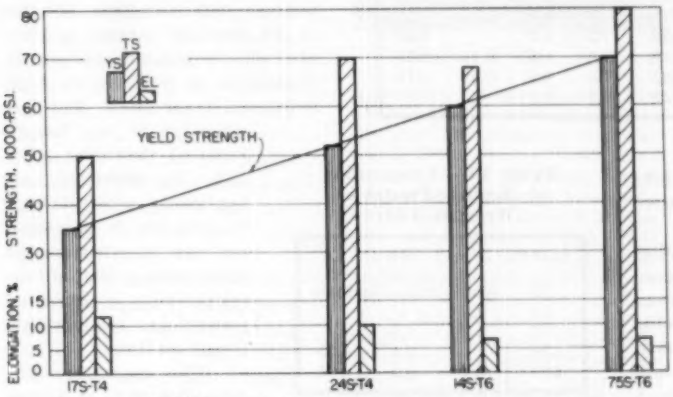


Fig. 2 — Yield Strength, Tensile Strength and Percentage Elongation of High-Strength Aluminum Alloy Extrusions. (Specification values for extrusions more than 1.5 in. in thickness)

Utilization of War Scrap

After VJ Day, one of the principal problems facing the aluminum industry was the economical utilization of the large quantities of "aircraft scrap". Numerous schemes were used to convert this scrap into useful form. Almost all of it contained around 4% copper, and contaminated to the extent that it was not satisfactory for making ingots for the wrought high-strength aluminum-copper alloys which require close control of the alloying elements. The scrap also contained appreciable magnesium but this element could be reduced to a satisfactory level by suitable fluxing treatment.

The aluminum foundries have always used large quantities of scrap and much of the aircraft scrap went to them. The aluminum-copper-silicon alloys, which already had achieved some degree of commercial acceptance, were admirable outlets for utilization of the available scrap, and a number of compositions were marketed with the copper usually in the range from 3 to 6% and silicon from 3 to 9%. (Generally the silicon exceeded the copper with their total less than about 12%.) Aluminum alloys of this type, with proper limits on the content of impurities, careful selection of scrap, and good melting practices, have proven eminently satisfactory for the production of castings, both with and without heat treatment.

One of these alloys, Alcoa 319, with a specially developed heat treatment, contributed to the successful substitution of light aluminum piano plates for the conventional cast iron. Other casting alloys were modified so as to permit higher impurity limits and have been surprisingly successful. All these factors contributed to the consumption of the tremendous supply of readily available aircraft scrap in a much shorter time than anticipated.

Table IV — Die Casting Alloys

Alloy	Cu	Si	Mg
13		12.0	
43		5.0	
85	4.0	5.0	
218			8.0
360		9.5	
380	3.5	9.0	
384	3.8	12.0	

New Alloys and Products

Trends in Aluminum Casting Alloys— In the postwar period, the aluminum-copper-silicon alloys continued to increase in favor for sand and permanent mold castings; alloys of the 319 type are being used extensively. A new permanent mold alloy, D132, is giving very satisfactory service for automotive pistons. Two new die casting alloys, 380 and 384, contain copper and higher silicon contents than the older alloy 85. Of the heat treatable

alloys, 355 and 356 are being favored for applications requiring good strength and ductility and, in the case of 356, resistance to corrosion.

Foundries that are not equipped with heat treating facilities resort to aluminum-zinc-magnesium alloys of the Frontier 40E type (Zn 5.5, Mg 0.6, Cr 0.5, Ti 0.2%), which require no solution heat treatment but are sometimes artificially aged.

The advantages of the aluminum-magnesium alloys are becoming more generally recognized. Several new modifications of the 214 alloy type have improved appearance after anodic treatment. Alloys containing about 6 to 7% magnesium are being publicized. The die casting alloy 218 (8% Mg) is now being used commercially for parts requiring greater strength and ductility than can be obtained with the other more easily cast alloys.

Table V — Composition of Wrought Magnesium-Silicide Alloys

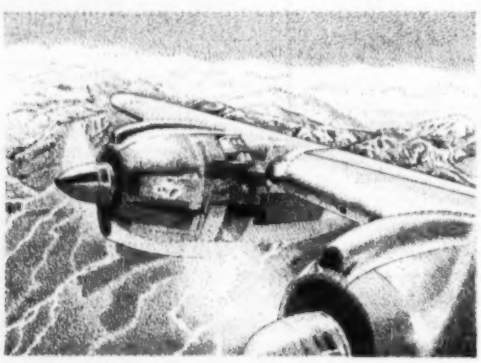
Alloy	Mg	Si	Cu	Cr
A51S	0.6	1.0		0.25
J51S	0.7	0.4	0.25	
53S	1.3	0.7		0.25
61S	1.0	0.6	0.25	0.25
62S	1.0	0.6	0.25	0.10
63S	0.7	0.4		

Table VI — Composition of Nonheat-Treatable Wrought Alloys

Alloy	Mn	Mg	Cr
2S	99.0% min. aluminum		
3S	1.2		
4S	1.2	1.0	
52S		2.5	0.25
56S	0.10	5.2	0.10

New Clad Products — Among other alclad products which received increased acceptance in the postwar period were Alclad 3S and Alclad 4S, the latter being used for high-quality corrugated industrial roofing sheet. Alclad pipe and tubing are important new products which permit aluminum to compete with other materials for condenser tubes and similar applications. Alclad sheet for beer barrels now has a corrosion resistant, high-purity aluminum surface. Similar products are applicable for handling many chemicals.

A clad product with a silicon alloy surface which takes a pleasing dark color after anodizing is being used for facing new buildings of modern architectural design.



Magnesium-Silicide Alloys — The alloy 63S (Table V) is one of the most important new peacetime alloys. Introduced by Alcoa just before the war, it became very popular as soon as peacetime activities were restored. This alloy, of the magnesium-silicide type, was developed initially for extrusions of intricate shape. Its excellent extrusion characteristics, together with its high resistance to corrosion and bright appearance after anodic treatment, led to a great many applications. It has proved very popular with architects because of its brilliant surface appearance after brightening and anodic treatments as well as its high resistance to corrosion. For this purpose it has largely replaced the older alloy 53S. An important new application, where its high resistance to corrosion and ease of extrusion are paramount, is that of tubing produced in enormous quantities for portable irrigation lines.

The magnesium-silicide alloy 61S, of higher strength than 63S, has become one of the most important structural aluminum alloys, having largely replaced alloy 53S for structural applications requiring good resistance to corrosion. Its use for railroad tank and hopper cars is established. Its high resistance to fresh and salt water lends it to uses such as canoes and other pleasure craft, lifeboats, and superstructures on ocean liners. Since its resistance to corrosion is not lowered by welding, it is also favored for welded structures and welding. For railroad passenger cars, a temper giving a ratio of tensile yield strength to ultimate strength less than 80% is being used. New tempers, produced by substantial cold working either before or after artificially aging the solution treated alloy, have resulted in a considerable increase in strength, opening up new fields of application for tubing and wire. For example, roofing nails easily manufactured in either of these tempers are now in common use. Rivets of 61S are now generally preferred over 53S rivets. A modification of 61S, designated 62S, with a reduced chromium content for better control of grain size under some manufacturing conditions, was recently introduced.

Nonheat-Treatable Alloys — The aluminum-magnesium nonheat-treatable alloys which were rather fully investigated and exploited to a limited extent in this country in 1935 have become more varied in composition in the postwar years. One alloy introduced and widely publicized by Kaiser Aluminum and Chemical Corp. under the designation 150S contains approximately 1.4% magnesium and has properties intermediate between 3S and 4S. However, since the alloy has no added manganese, it has a brighter color after anodizing than either 3S or 4S and is considerably lower priced than 52S, which had been previously used for its attractive appearance after an anodic treatment. Other aluminum alloy manufacturers are now supplying sheet of the 1¼% magnesium type.

There is also renewed interest in this country in alloys of higher magnesium content, ranging from 3½ to 5% magnesium. Since they achieve their strength without heat treatment, they are of considerable interest for welded parts, especially with the new inert-gas-shielded arc welding methods which require no flux.

Edgar H. Dix, Jr.

ALUMINUM and its applications have been the prime interest of EDGAR DIX since his graduation from Cornell in 1914. During World War I he was chief of the testing department of the Pittsburgh laboratories of the Bureau of Aircraft Production and later, at McCook Field, chief of the metals branch of the engineering division, U. S. Air Service. In 1923 he joined Aluminum Co. of America, became chief metallurgist of the research laboratories in 1930 and is currently assistant director of research. In 1947 he was awarded the Clamer Medal of the Franklin Institute for his contributions to the development of high-strength, corrosion resistant aluminum products.

Brazing Alloys — With the development of suitable fluxes for brazing, aluminum alloy assemblies may now be economically made by methods similar to those employed for other metals. Aluminum alloys containing from 5 to 12% silicon are the preferred filler materials for articles required to meet severely corrosive conditions. By the addition of copper or both copper and zinc to an aluminum-silicon alloy, brazing alloys of lower melting points have been developed. Of the wrought alloys, the nonheat-treatable alloy 3S is most commonly used for brazed assemblies. Since 3S is fully annealed by the temperature of brazing, higher strength assemblies are obtained with 61S and J51S alloys of the magnesium-silicide type; assemblies may be quenched from the brazing temperature or, in the case of thin sheet, cooled in an air blast, and subsequent artificial aging will produce maximum strength. These alloys, however, require lower brazing temperatures than 3S. Where castings are included in the brazed assembly, alloys of the aluminum-zinc-magnesium type (A612 for sand castings, C612 for permanent mold castings) are preferred because of their higher melting point.

A unique and favorable feature has been a brazing sheet having a core of either 3S or a heat-treatable magnesium-silicide alloy clad on one or both surfaces with a suitable brazing alloy. The use of these clad products avoids the necessity of locating separate pieces of the filler alloy in the assembly to be brazed.

Aluminum Alloy Bearings — Aluminum bearing alloys, although they were developed and had passed through the testing stage prior to the war, have become of increasing importance during the postwar years. The basic alloy, Alcoa 750, contains 6½% tin and 1% each of nickel and copper. Several other modifications have special characteristics. Permanent mold cast aluminum bearings found their first important application in diesel engines where their high fatigue resistance, satisfactory embeddability, and good resistance to corrosive attack by organic acids formed by the oxidation of lubricating oils during service, make them superior to other bearing materials. Their use for main bearings, cam bearings and auxiliary drive shaft bearings in aircraft engines has now been approved on the basis of dynamometer tests and actual service.

High Production

The theme of this year's National Metal Congress is "High Production". This is a welcome theme to an industry which in a little over a year doubled the production rate it had taken 50 years to achieve; then, not stopping, so increased its capacity that in the midst of a world war it could cut back about half in order to save coal and manpower. The aluminum industry views with confidence the years ahead — through research, aluminum alloy development will keep pace with the increasing requirements.

Critical Points

Improved Heating Furnaces

IN WALKERVILLE, Canada, W. B. TURNER, chief engineer for Dominion Forge & Stamping Co., showed THE EDITOR some interesting improvements in 6-ft. heating furnaces of the well-known "slot" type — interesting, in the first place, because they are movable units constructed within stout steel boxes. Furthermore the legs are welded to a horizontal steel frame which in turn snugs into a matching frame, the two being separated by a number of stiff coiled springs which absorb the shocks and jars transmitted through the earth from nearby hammers — a "beauty-rest" that saves the furnace from vibration damage. At Dominion Forge all furnaces, and there are 65 of them of various sizes ranging from 10 to 33 sq.ft. hearth area, are pyrometrically controlled; one specialist on each shift does nothing but inspect pyrometers and burners. Each furnace has an automatically proportioning burner centrally located in each end wall; a Bristol radiation pyrometer is fixed in the center of the back wall. (As was to be expected, it was hard at first to convince some of the hammer men they must rely on the pyrometer dial rather than on their educated eye.) Exhaust flame blows out the slot, and up the front wall behind an asbestos baffle, bathing enroute a flattened 10-in. steel pipe that is an effective preheater for combustion air. (Each furnace has its own small Spencer turbine.) Fuel is bunker oil, preheated to 225° F. To avoid stoppages in cold weather the distribution system is continuously pumping and circulating three times the expected consumption and the oil pipe is paralleled by a live steam pipe, the two being tied together inside thick insulation. Each furnace is thus a self-contained portable unit, plugged in electrically and tied into the oil mains by flexible tubing.

Most notable are the savings due to improved refractories. Previously the standard construction at Dominion Forge & Stamping Co. was to line the steel furnace shell with a single layer of low-temperature insulating brick, and then put in an inner lining of firebrick. The roof is an arch; the lintel over the slot is of grooved tile which key together. The shell is strongly buckstayed and tied together with channel irons — really stout. Insulating firebrick are now capable of resisting high temperatures, and to test the idea two new shells were lined, one in the conventional manner described, and the other using insulating brick, block and shapes exclusively except for a layer of crushed dolomite on the hearth. Interior lines and burner arrangements were identical. The two were put into service simultaneously, flanking a single high-production hammer. The all-insulated furnace ran on 75% of the fuel oil required by the other one! Subsequent operations confirmed other advantages and warranted the reconversion of all the furnaces. Maintenance is no higher, making allowance for the fact that one-shift operation, with its nightly chilling, is much harder on furnace linings than continuous operation. Workmen's comfort is improved — less heat is radiated into the shop. The "light-up" time in the morning is only one hour. No troubles have been found with the linings of all-insulating brick except when a large furnace is heavily driven beyond its normal capacity of about 2½ tons per hr. This occurs sometimes when its heating capacity is not quite equal to the hammer's production on an easy part.

Dominion Forge & Stamping Co. has everywhere evident those characteristics expected in modern shops, first evidenced by a very high standard of housekeeping. Handling equipment and teams of helpers combine to keep the hammer working at highest productivity — obviously a proper way to manage things, since the hammer and the forgeman are the two expensive units.

The Case of Edouard Houdremont

THREE letters have reached THE EDITOR asking aid for Edouard Houdremont, noted German metallurgist and former Krupp executive, in his attempt to revise his prewar books that enjoyed a considerable vogue in Europe. Dr. Houdremont at this time is imprisoned in War Criminal Prison No. 1, Landsberg on Leach, Bavaria. In an attempt to get a few facts to aid him in properly disposing of these appeals for help, THE EDITOR addressed an inquiry to Col. W. R. Graham, prison director at Landsberg, who has replied as follows:

> "1. Please be advised that prisoner Edouard Houdremont has been sentenced for employing concentration camp inmates and prisoners of war in German industrial plants for slave labor. Should you desire more detailed information on this subject, it is suggested that you contact the Office of the United States High Commissioner for Germany, Office of General Counsel, A.P.O. 897, U. S. Army, % Postmaster, New York City.
>
> "2. Prisoner Houdremont has been hospitalized on several occasions and is presently convalescing and receiving treatment for tuberculosis."

America is pre-eminent in alloy steel production, yet most economical in alloy consumption and meticulous in quality specifications. Substitution of high-grade carbon steels will be more than offset by consumption in the new-born industries of the subatomic, supersonic future.

Midcentury Review of Progress in S.A.E.-A.I.S.I. Alloy Steels

THIS ACCOUNT — space limits it to little more than an abstract — will deal principally with significant events which occurred throughout the last 60 years in the development and production of what are now known as the S.A.E.-A.I.S.I. alloy steels. The effects of simplification and standardization, as well as broadening markets and the future of alloy steels, will be the topics, rather than events of a purely technical nature. Scientific developments in these years will be touched upon only to establish the period when the American industry entered production.

First — a definition: Unless otherwise specifically mentioned, this discussion will be confined to those steels now known as the S.A.E.-A.I.S.I. alloy steels. Such steels are also known as "constructional alloy steels", a generic term applied throughout World War II to distinguish S.A.E.-A.I.S.I. steels (or their equivalents containing less than 4% chromium) from other categories of alloy steels such as stainless or heat resisting steels, electrical silicon sheets, toolsteels, proprietary grades of so-called high-strength steels, or special analyses for ordnance or aircraft.

Review of Early Developments — As early as 1820, nickel and manganese steels were prepared by Faraday and Stodard in Great Britain. This appears to be the first study of alloy steel. In 1821 Berthier, in France, experimented with 1% carbon, 1.5% chromium steels and stated that "it made excellent razors and knives". This steel resembles our 52100 bearing steel of today.

A review of the literature indicates that alloy steels similar to our present S.A.E.-A.I.S.I. 2300 and 2500 series of nickel steels were developed between 1850 and 1885 as a result of studies by eminent British scientists. They also originated the 13% manganese steel, the low-carbon, high-silicon electrical sheet, and toolsteels containing tungsten and some straight chromium toolsteels.

Generally, our literature survey indicates that nickel steels are the result of work by the British, nickel-chromium steels similar to our 3300 series were developed in Germany and called "Krupp steels", and silico-manganese steels similar to 9200 were principally French. All these originated prior to 1900. Chromium steel for crusher parts and abrasion resistance was an American invention; an offshoot of it was the 0.60% chromium structural steel made in 1870 and used on the Eads Bridge spanning the Mississippi River. This steel was a generation ahead of its time.

There are indications that the ancestor of the 3100 nickel-chromium steels came into existence prior to 1890 in the United States as a result of remelting of unidentified chromium and nickel bearing mixed scrap, a circumstance not difficult

By John Mitchell
Assistant to Manager of Sales, Alloy Division
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Pittsburgh

Table I — Estimated Grade Mix of Total S.A.E.-A.I.S.I. Ingot Production, 1900 to 1950

Does not include stainless steels, electrical silicon sheet, toolsteels, proprietary grades of low-alloy, high-strength steels, nor cast alloy steels

Year	Basic Types of Alloy Steels										All Other	Ingot Production
	Ni (1)	Ni-Cr (2)	Cr (3)	Mo (4)	Cr-Mo (5)	Ni-Mo (6)	Cr-Ni-Mo (7)	Mn (8)	Cr-V (9)	Si (10)		
1900	90%	10%										3,000*
1910	40	30							24%	3%	3%	150,000*
1920	20	33	5%				1%	3%	32	5	1	1,078,000†
1930	12	35	11		5%	3%	3	5	17	7	2	2,232,000†
1939	5	40	12	5%	7	7	4	4	4	9	3	2,433,000†
1943	5	4	11	7	9	3	47	2	1	10	1	10,000,000†
1950	2	3	16	8	13	8	37	3	1	7	2	6,000,000*

*Estimated.

†Adjusted for S.A.E.-A.I.S.I. alloy tonnage only.

NOTES: 1—2000, 2100, 2300, and 2500 series and includes all other nickel steels.

2—3000, 3100, 3200, 3300, and 3400 series and includes all other nickel-chromium steels.

3—5000, 5100 and 5200 series and includes other chromium steels.

4—4000 series; includes Mn-Mo steels.

5—4100 series; includes 2 to 3% Cr-Mo steels.

6—4600 and 4800 series.

7—4300, 8600, 8700, 9400, 9700 and 9800 series and includes all other Cr-Ni-Mo steels.

8—1300 series and includes 13% Mn steels.

9—6100 series; includes carbon-vanadium steels.

10—9200 series; includes other high-silicon steels.

to conceive in early melting practices. This steel could thus have been accidental rather than planned. Its specific origin is difficult to trace because many early European developments were held secret because of their military importance.

A review of British and other foreign specifications since 1890 shows that the long trend has been toward alloy steels rich in nickel or nickel-chromium. This trend prevailed as late as 1944 but has since been changed. In America, as shown in Table I, the trend has been the reverse from the beginning.

To digress momentarily, it might be observed that we in America have control of or access to nickel, molybdenum and vanadium, but we use these important alloying elements very sparingly, while Europeans (who have less control) used them rather freely in the past. To illustrate further, during World War II the Russians had to resort to high-silicon chromium-manganese steels because of restrictions on the use of other more desirable alloying materials, the Germans ended up the war that way, and the British changed gradually to the American methods of economical use of preferred alloys. This is mentioned to compare the logic of our approach as compared with that of other countries. It certainly indicates that the source of raw material supply or control should definitely influence the basic compositions devised.

Table II — Automobile Steel Specifications, 1898

Part	Material Specified	Probable Material Furnished
Crankshafts	Axle steel	3½% nickel steel
Connecting rod	Bronze	—
Front wheel axles	Soft steel	1020 or 1030
Countershaft	Nickel steel	3½% nickel steel
Piston pin	Toolsteel	—
Differential bevel gears	Cast steel	1020 or 1030
Rear springs	Oil tempered steel	9250 or 1095
Rear axle rollers	Stubs steel	3½% nickel steel

1890 to 1899; Primary Introduction Period

In 1890 the United States Navy investigated nickel steels for armor and in 1891 adopted it for use in naval craft. Between 1891 and 1895 Navy armor of hard faced (carburized) Harvey "patented process armor" made of 4 to 5% nickel steel was used on the battleship Oregon; nickel steel was used in bicycle parts and for a large shaft for the Ferris wheel at the Chicago World's Fair; naval ship shafting of nickel steel was also produced in this country about this time. These events marked the introduction and a trend in the manufacture of alloy steels in the United States. As mentioned before, structural alloy steel was made for the Eads Bridge in 1870, but this was far before its time and had very little to do with the heat treatable alloy steels which were to follow.

Between 1895 and 1900, steels such as the 2300 nickel steels and the 3100, 3200, and 3300 series of nickel-chromium steels were made and used for parts in some of the first American automobiles, the steels similar to the 3½% nickel steels

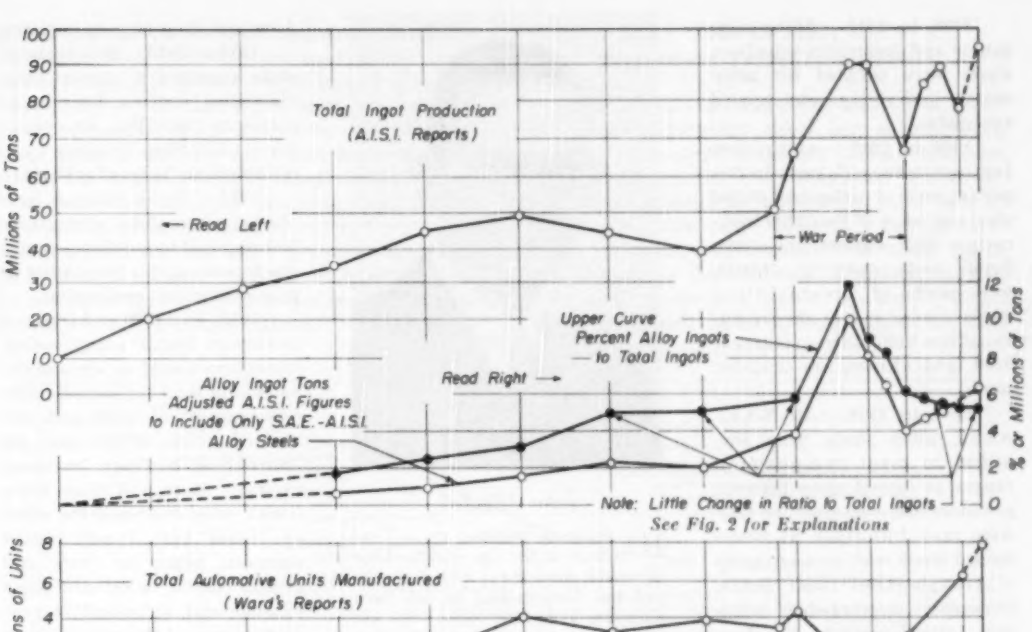

Fig. 1 — Annual American Production of Steel Ingots Has Increased at an Average Rate of About 15½ Million Tons in Each Decade Since 1900. Wrought alloy steels are also increasing at a healthy rate, but proportion of alloy to total steel is about the same postwar as in the 1930 decade — namely 5½%

(2300) predominating. These were manufactured in small openhearth furnaces (acid or basic) or in crucible furnaces by several of the older steel companies.

The American Society for Testing Materials, A.S.T.M., was formed in 1898 and in 1901 the first nickel steel specification was written (Bulletin No. 13) covering 3½% nickel steel axles; later Bulletin No. 15 was issued covering nickel steel forgings.

Table II gives a bill of materials, although somewhat vague, illustrating the typical specification requirements for parts by one of the original automobile manufacturers in 1898.

1900 to 1910; Secondary Production and Development Period

Between 1900 and 1910 events occurred which have since had a pronounced effect upon present grades and uses of alloy steel, as well as upon the production and manufacturing practices. The more important steps were as follows:

1900 — 4000 automobiles were made and about 3000 tons of alloy steel ingots were produced.

1900 to 1902 — Vanadium steels were studied by Arnold in Great Britain.

1902 to 1905 — Chromium-vanadium steels were studied in the United States.

1900 to 1905 — Silico-manganese steel, oil quenched, was tried for springs.

1905 — Rich vanadium bearing ores were discovered in Chile, South America.

1905 — The Society of Automobile (now Automotive) Engineers, S.A.E., was formed.

1905 — 25,000 automobiles were made and about 20,000 tons of alloy steel ingots were produced.

1906 — The first electric furnace made steel in this country.

1907 — The first openhearth heat of chromium-vanadium steel was tapped and chromium-vanadium steel was adopted for many automobile parts — the first departure from nickel or chromium-nickel.

1909 — S.A.E. held the first Standards Committee meeting.

1906 to 1910 — Silico-manganese and chromium-vanadium steels were adopted for automobile leaf springs and proved successful.

1900 to 1910 — Antifriction bearings were made early in this period, some of carburized nickel steel and some of the 52100 high-carbon high-chromium steels. Small tools, such as chisels, were made of several alloy steels similar to our chromium-vanadium 6100, silico-manganese 9200, and chromium-tungsten steels.

1900 to 1910 — All S.A.E.-A.I.S.I. alloy steels were furnished to meet composition ranges as agreed upon between producer and consumer, or they were merchandised as trade-named steels with no assurances of composition range limits. Consumers directed their attention toward learning the fundamentals of annealing, heat treating or machining of the new steels, while producers' efforts were directed toward manufacturing problems and improvement of steel quality. Internal soundness of steel had not as yet been regarded as a specification requirement.

John Mitchell

HE STARTED working as a heat treater at the age of 17. Continuously since then, with Republic and the Corporation, he has been wrestling with alloy steels. He was chairman and sparkplug of the War Production Board's advisory committee that devised the National Emergency steels.

1911 to 1920; Primary Transition Period

1911 — 210,000 automobiles were manufactured and about 150,000 tons of alloy ingots poured. The cost of alloy steel was usually considered to be high and much thought was given to modifications resulting in new and cheaper steels.

1912 — The S.A.E. issued its first list of steel specifications, as shown in Table III.

1912 — Results of the first Indianapolis motor speedway race emphasized the need for better properties in steel, stimulating more research and development of better steels.

1913 — Pretreated nickel-chromium (3250) die block steels were introduced and used by the American drop forging industry.

1913 to 1915 — Heat treaters' clubs appeared in various manufacturing centers, later to be combined into the American Society for Steel Treating (now the American Society for Metals).

1914 — More than a half million automobiles were manufactured and mobile farm implements were being considered as practicable for production.

1916 to 1920 — Airplane producers began using nickel, chromium-nickel or chromium-vanadium steel for engine parts. Consumption of 52100 and carburized 3½% nickel steel by antifriction bearings increased rapidly. More and more autotrucks were built and the effect of World War I and import demands began to show still greater effects. Alloy steel ingot tonnage and automobile production passed the million mark for the first time. The scarcity of vanadium began to influence the thinking on new steels. Molybdenum steels were patented and the metal was produced from Colorado mines. In this period new alloy steel companies also entered the field. 3240 nickel-chromium steel was adopted for Liberty engine crankshafts and 4340 steel was developed for Liberty cranks, introducing chromium-nickel-molybdenum steels. "Flakes" (internal ruptures in large steel sections) were being studied seriously for the first time. The 4100 chromium-molybdenum and 5100 chromium steels began to replace chromium-vanadium automobile parts. The 4100 chromium-molybdenum steels were also tried in small tools, and chromium-

Table III — First S.A.E. Steel Specifications, 1912

Nickel Steels	Nickel-Chromium Steels			Chromium Steels	Chromium-Vanadium	Silico-Manganese
	Low	Medium	High			
23-15	31-15	32-15	33-15	51-95	61-15	92-50
23-20	31-20	32-20	33-20	51-120	61-20	
23-25	31-25	32-25	33-25	52-95	61-25	
23-30	31-30	32-30	33-30	52-120	61-30	
23-35	31-35	32-35	33-35		61-35	
23-40	31-40	32-40	33-40		61-40	
23-45	31-45	32-45	33-45		61-45	
23-50	31-50	32-50			61-50	
					61-95	

nickel-molybdenum die blocks appeared. Hadfield's manganese steel (13% Mn) was made in the open-hearth furnace for helmets, rapid transit rails, and track crossings. Tank and gun parts were made of nickel, chromium-nickel and chromium-vanadium steels. Some of the alloy steels used in automobiles, cranks for example, were changed to carbon steel — the first major departure from alloy steel. Stanley Rockwell invented his hardness tester. Deoxidation practice, grain size and better quality control were being studied. Control of macro-etch, nonmetallic inclusions, and internal ruptures presented the steel industry with perplexing problems. The alloy grade

1921 to 1930; Secondary Transition Period

1921 to 1925 — A decreasing amount of nickel and nickel-chromium steels and an increasing amount of chromium-vanadium, carbon-chromium, and silicon-manganese steels were used. 4100 Cr-Mo steels were adopted for automotive parts such as axle shafts, arms and knuckles. Patents were issued on nickel-molybdenum 4620 steel, which was adopted for the first time for differential ring gears and antifriction roller bearings. Mobile tractor parts were made of chromium-nickel 3100

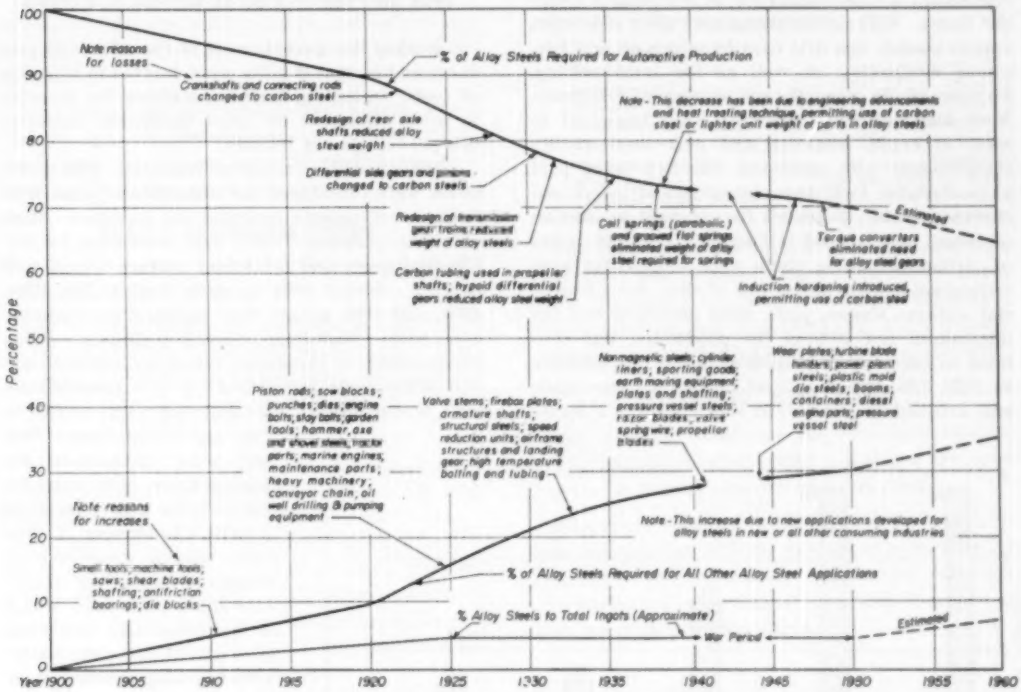
Percentage
Year 1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
Note reasons for losses
% of Alloy Steels Required for Automotive Production
Crankshafts and connecting rods changed to carbon steel
Redesign of rear axle shafts reduced alloy steel weight
Differential side gears and pinions changed to carbon steels
Redesign of transmission gear trains reduced weight of alloy steels
Carbon tubing used in propeller shafts; hypoid differential gears reduced alloy steel weight
Note - This decrease has been due to engineering advancements and heat treating technique, permitting use of carbon steel or lighter unit weight of parts in alloy steels
Coil springs (parabolic) and grooved flat springs eliminated weight of alloy steel required for springs
Torque converters eliminated need for alloy steel gears
Induction hardening introduced, permitting use of carbon steel
Estimated
Piston rods; saw blocks; punches; dies; engine bolts; stay bolts; garden tools; hammer, axe and shovel steels; tractor parts; marine engines; maintenance parts; heavy machinery; conveyor chain; oil well drilling & pumping equipment
Valve stems; firebox plates; armature shafts; structural steels; speed reduction units; airframe structures and landing gear; high temperature bolting and tubing
Nonmagnetic steels; cylinder liners; sporting goods; earth moving equipment; plates and shafting; pressure vessel steels; razor blades; valve spring wire; propeller blades
Wear plates; turbine blade holders; power plant steels; plastic mold die steels; booms; containers; diesel engine parts; pressure vessel steel
Note reasons for increases
Small tools; machine tools; saws; shear blades; shafting; antifriction bearings; die blocks
Note - This increase due to new applications developed for alloy steels in new or all other consuming industries
% of Alloy Steels Required for All Other Alloy Steel Applications
% Alloy Steels to Total Ingots (Approximate)
War Period
Estimated

Fig. 2 — Despite the Great Increase in Number of Automobiles Made Each Year (Bottom Line on Fig. 1) the Proportionate Amount of Alloy Steels Used in That Industry Is Steadily Giving Way to Hundreds of Uses by Thousands of Other Consumers

mix of the country was beginning to form a different pattern (see Table I).

All these and many more, which space will not permit mentioning, contributed to the fast moving transition period brought on principally by *(a)* the war, *(b)* the shortage of vanadium, *(c)* the introduction of molybdenum, *(d)* increased automotive production, and *(e)* spread of technical information.

steels. New alloy steel producers entered the field. Railroad companies adopted carbon-vanadium alloy steels for locomotive axles and side rods and silico-manganese (9200) or chromium-vanadium (6100) for springs. Makers of oil drilling equipment adopted S.A.E.-A.I.S.I. 3100 and 2300 series for rotary cutters and other drilling equipment parts. 5% nickel steel and 3310 chromium-nickel steel were being used extensively for heavy-duty gears.

1926 to 1930 — Railroads adopted 1½% nickel steels for boiler stays. Grain size control was perfected and adopted in specifications. Nonscaling atmospheres were being used in automatic heat treating furnaces. Alloy steel production reached 6% of the total ingot production, a proportion which has never been bettered except during World War II. The 4 to 6% chromium steels were studied, adopted and used for cracking still tubing in oil refineries. New aircraft engine builders and airframe manufacturers entered the field; weldable tubing and aircraft sheets of S.A.E.-A.I.S.I. 4130 Cr-Mo steel were first produced. Nitralloy, a foreign chromium-molybdenum-aluminum steel, was introduced in this country for aircraft engine cylinder liners. 1320 carbon-manganese alloy steel wire, copper coated, was first used by telegraph and telephone companies, as well as for levee netting, because of its strength and corrosion resistance. Steel manufacturing practices were improved to meet aircraft, bearing and gear steel quality requirements with particular attention being paid to nonmetallic inclusions, subsurface stringers and carbide streaks. Facilities for enlarged production of nickel were opened in Canada. The 1300 series of carbon-manganese steels were adopted for noncritical automotive parts. Use of alloy steels in special sections, shapes, plate, sheet and strip was not uncommon, but 90% of the production was confined to bars and semifinished billets and blooms. In 1929, 3,855,000 alloy steel ingot tons were made and automobile production was 5,358,000, a figure that was not exceeded until 1949. Alloy steel capacity was increased to meet increasing consumer demands.

By 1930, most all producers and significant users of alloy steels had expanded their metallurgical departments and research laboratories. Technical forces were increased to study problems. The theme song was "more exacting demands and cheaper alloy steels". Knowledge of the physicochemical laws of steelmaking and steel treating had been deepened and greatly broadened. The stage was set to meet an entirely new group of conditions brought about by the depression.

1931 to 1940 — The Depression Period

During this period, most of the efforts of producer and consumer alike were devoted to lowering of costs, presenting further problems for research to solve. Some of the most significant events of this period were as follows:

1931 to 1935 — Carbon-molybdenum, 4000 series, steels were introduced for automotive parts, with issuance of patents covering the analyses. High nickel-molybdenum (4800) was introduced for differential gears and for rotary cutters for oil well drilling. Sucker rods of alloy steels (1300, 2300, 4800, and 4600 series) were adopted for pumping of oil wells. High-temperature bolt steels of varying compositions of chromium, vanadium, molybdenum and silicon were introduced. A ½% molybdenum steel proved useful in high-temperature service in plate and tubing form. 3045 steel was introduced for steering arms; 5000 series for transmission gears; localized induction hardening of steel parts became commercial. Manganese-vanadium steels were studied and later adopted for locomotive side rods, axles and boiler plate. Controlled cooling practices were devised to eliminate internal ruptures.

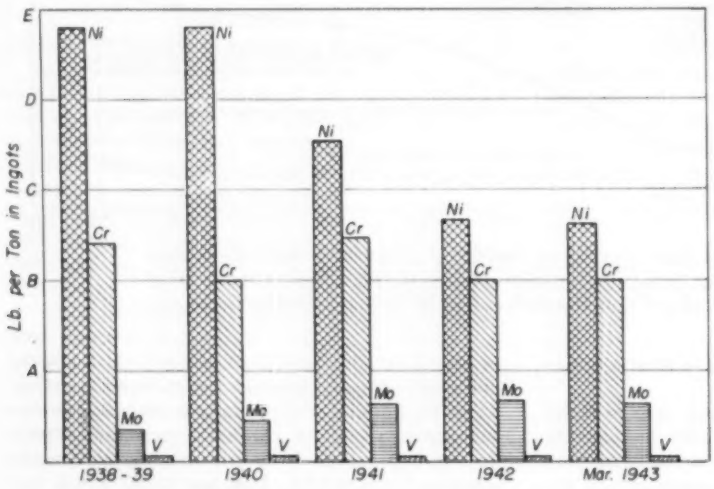

Fig. 3 — Relative Amounts of Common Alloying Elements Required to Make Constructional Steels, 1938-1943. Vertical scale expressed in arbitrary but uniform increments to prevent disclosure of production of certain mills

1936 to 1940 — Molybdenum steels of the 4000 series were sulphurized to ease gear machining problems. Cr-Ni-Mo-Cu steel was introduced for die blocks. Medium-carbon gears, induction hardened, replaced oil quenched alloy steels in tractor drives. Magnetic particle inspection methods (Magnaflux) were introduced into standards of

Why

NICKEL SILVERS

constantly increase in popularity

NICKEL SILVERS are a group of lustrous copper-base alloys whose colors range from light pink to silvery white, depending on composition.

Their impressive beauty and moderate cost... and the fact that they can be readily cast and worked by ordinary methods... contribute to their great popularity.

Essentially copper-nickel-zinc alloys, their strength and corrosion-resistance in most cases exceed those of the corresponding brasses and bronzes, depending on nickel content.

MANY DIFFERENT TYPES

Nickel silver alloys may be: (1) hot-worked, (2) cold-worked and (3) cast.

The wrought forms are available as rods, wire, sheets, and tubes in many degrees of temper ranging from the *soft* types for drawing, spinning and forming, to the *very hard* required for flat or coiled springs.

In the harder tempers, nickel silvers develop relatively high tensile strength. For example, they reach approximately 145,000 p.s.i. in spring wire... obviously, an excellent material for small parts subject to considerable stress. Moreover, wrought nickel silvers are furnished in various ranges of grain size, from "fine" for polishing and etching, to "large" for forging and coining. Die cast and extruded shapes are also available.

ECONOMICAL TO FABRICATE

Nickel silvers promote economy and speed in fabricating all sorts of products. Applications include tableware, hollow ware, springs, keys, slide fasteners, weather stripping and parts for radios, television, telephones, typewriters, musical instruments, cameras, optical goods, fishing tackle and thousands of other articles.

CAST NICKEL SILVERS may be matched in color with the wrought forms. They are also complementary to chromium-nickel stainless steels and Monel®.

Nickel silver castings containing 20 per cent nickel are silvery white all the way through and exhibit the following properties:

Tensile Strength (cast)	40-60,000 p.s.i.
Yield Point (.5% ext.)	20-32,000 p.s.i.
Elongation in 2"	15-25%
Reduction of Area	15-30%
Coefficient of Expansion	0,0000091 per degree F.
Specific Gravity	8.70-8.90
Weight per cubic foot	540-550 lbs.
Brinell Hardness	75-100 (1000 kg. load)
Shrinkage (inches per foot)	3/16
Machinability	Readily machined by all methods

The cast forms are widely used by architects, decorators and builders, and extensively in hardware, packaging machinery, bottling machinery, dairy equipment and plumbing goods. Centrifugally cast cylinders and leaded bearings are also available.

COUNSEL AND DATA

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Data collected by Norman S. Mott, Chief Chemist and Metallurgist, The Cooper Alloy Foundry Co.

Alloy Castings for Moderate Temperatures

Alloy	700°F	750	800	850	900	950	1000	1050	1100	1150	1200	Rating
PCS			13,200				3,700					1% 10,000 Hr.
A.S.T.M.			12,000		4,600		1,750					1% 100,000 Hr.
A 216 - 47 T Grade WCA	11,640	10,400	8,750	6,825	4,900							Design stress
CMS			35,000		27,500		11,800					1% 10,000 Hr.
A.S.T.M.			25,000		11,800		5,650					1% 100,000 Hr.
A157 - 44 Grade C 1		12,250	11,820	10,500	8,925	7,000	4,375					Design stress
2 Cr												1% 10,000 Hr.
A.S.T.M.			27,000		15,750		7,200		3,300		1,550	1% 100,000 Hr.
A157 - 44 Grade C 3A		12,425	12,250	11,725	9,650	7,220	5,120	3,370	1,925			Design stress
5 Cr			36,000		20,000		11,900		5,000		2,500	1% 10,000 Hr.
A.S.T.M.			22,500		12,000		6,800		3,000		1,000	1% 100,000 Hr.
A157 - 44 Grade C 5A		12,425	12,250	11,725	9,650	7,220	5,120	3,370	1,925			Design stress
9 Cr					24,500		8,200	5,425	3,600	2,400	1,600	1% 10,000 Hr.
A.S.T.M.					15,000		6,500		1,300		700	1% 100,000 Hr.
A 157 - 44 Grade C 12		18,000	16,500	14,000	11,000	8,300	5,800	3,800	2,500	1,600	1,000	Design stress
12 Cr			30,000		11,000		7,500					1% 10,000 Hr.
			21,000		9,000		4,500		2,050		970	1% 100,000 Hr.
A.C.I. CA-15	12,700	11,400	10,070	8,225	5,775	3,675	2,100	1,150	680	430	300	Design stress
18 Cr							8,500[W]		5,000[W]		2,200[W]	1% 10,000 Hr.
A.C.I. CB-20							7,000[W]		4,500[W]		1,600[W]	1% 100,000 Hr.
					[W] For wrought material; no data available for castings.							Design stress

Alloy Castings to Resist High Temperatures

Alloy	1000°F	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	Rating
27 Cr					735							1% 10,000 Hr.
A.C.I. HC-30												1% 100,000 Hr.
					725	500	300	150	70		40	Design stress
18-8	22,500	17,000	9,000									1% 10,000 Hr.
A.C.I. CF-15	9,800	6,100	3,850	2,400	1,500							1% 100,000 Hr.
	8,750	5,300	2,700	1,700	1,100	700						Design stress
25-12		10,000		6,100	5,600	4,200	3,150	2,300	1,675	1,200	810	1% 10,000 Hr.
A.C.I. HH-35					4,400		2,300		1,100		570	1% 100,000 Hr.
	9,600	8,000	6,400	4,950	3,600	2,450	1,600	1,150	775	500	300	Design stress
25-12					9,500		4,800		2,400			1% 10,000 Hr.
A.C.I. HH-45												1% 100,000 Hr.
	12,350	10,200	8,150	6,200	4,475	3,000	2,000	1,350	925	600	400	Design stress
25-20					5,800		3,800		2,250		750	1% 10,000 Hr.
A.C.I. HK-30												1% 100,000 Hr.
					2,900	2,600	1,900	1,550	1,100	700	375	Design stress
35-15 (35 Ni, 15 Cr)					7,800	6,600	5,000	3,200	2,000	1,040	480	1% 10,000 Hr.
A.C.I. HT-40							3,350		1,150		100	1% 100,000 Hr.
	10,025	8,300	6,500	5,000	3,700	2,550	1,600	990	570	330	250	Design stress
60-12 (60 Ni, 12 Cr)							3,100		1,100			1% 10,000 Hr.
A.C.I. HW-45												1% 100,000 Hr.
	7,600	5,900	4,500	3,250	2,225	1,450	880	520	300	200	150	Design stress

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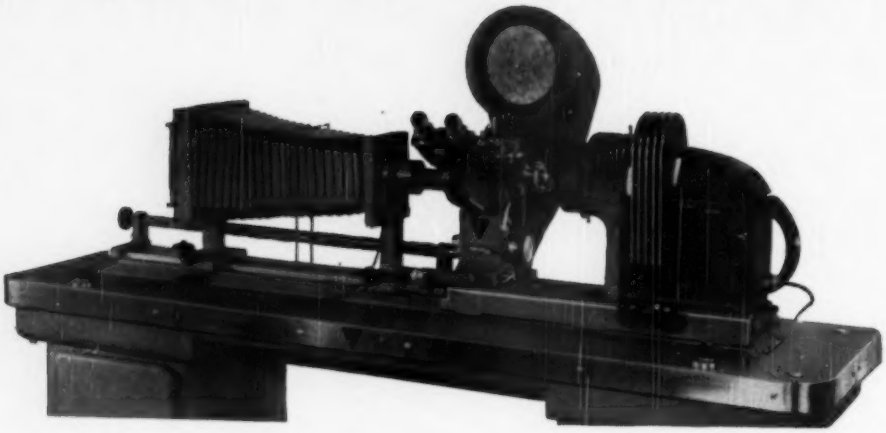

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acceptance for aircraft steels. Titanium, columbium, silicon and molybdenum were added to 2 to 5% chromium high-temperature steels to improve scaling or creep resistance. Research on hardenability factors started, and a convenient hardenability test devised. Boron treated steels appeared. The carbon-manganese steels, 1330, 1335, and 1340, were adopted for automotive transmission gears, axles, knuckles and arms to effect desired economies. 4130 chromium-molybdenum sheet and strip was formed into gas cylinders (high pressure) and 2315 nickel steel for pressure vessels. The chromium range was changed on 5100 steels to effect economy. Trends toward use of lower nickel and higher molybdenum in alloy ingots are shown in Fig. 3. Many modifications at this time were made in alloy steel specifications, becoming so numerous by 1938 that the American Iron and Steel Institute's alloy technical committee, joined later by the Society of Automotive Engineers' committee on steel specifications, embarked upon a study of alloy steels to determine:

A. What should be done to reduce number of basic varieties or types.

B. What should be done to reduce number of grades within each.

C. How consumer and producer could benefit from these studies with a view toward standardization and simplification.

The result of this study revealed that consumer demands involved no less than 50 basic varieties or types and more than 3000 variations in grade or analysis. This obviously was an impractical situation. It also was perfectly unnecessary, as was apparent from the existing knowledge of the specific functions of alloying elements in steel. After considerable coordination between the two technical groups, a list of about 10 basic series and 125 grades was set up as the significant S.A.E.-A.I.S.I. standard steels of the country. This was most fortunate — as we soon learned. By their cooperative efforts, consumers gained as much in this move as the producers did, if not more, since composition limits for carbon, manganese and chromium were narrowed, a matter which had been controversial between consumer and producer for many years. Incidentally, the change was made at no increased cost to the consumer.

The author, therefore, would label the 1930's as the simplification period that furnished, unknowingly at the time, the groundwork for still greater production, standardization and simplification, and eased the task of both consumer and producer during the ensuing war period.

Table IV — Product Mix by Mechanical Properties, Consumer Industries and Applications

% of all alloy steel produced	30%	30%	15%	15%	10%
Tensile strength range	110,000 to 225,000 psi.	110,000 to 225,000 psi.	190,000 to 240,000 psi.	275,000 to 325,000 psi.	Up to 125,000 psi.
Compositions	Under 0.25% C; Ni, Cr, Mo	0.25 to 0.70% C; Ni, Cr, Mo, B	0.35 to 0.90% C; Si, Ni, Cr, Mo, V, B	0.90 to 1.15% C; Ni, Cr, Mo, V	0.05 to 0.15% C; Ni, Cr, Mo, Mn, Si, V, W and Al
Heat treatment	Carburize, quench and temper	Quench and temper	Quench and temper	Quench and temper	Various
Products furnished	Bars, billets, blooms	Bars, billets, blooms, slabs	Bars, billets, flats, blooms, shapes	Bars, billets, blooms	All products
Industries served	Automobile, truck, tractor, oil well, bearing, aircraft, mining, railroad, machine tool	Automobile, truck, tractor, oil well, aircraft, machine tool, mining, railroad	Automobile, truck, tractor, small tool, aircraft, machine tool, mining, railroad	Automotive, bearing, small tool	Oil refining, oil well, power, chemical, railroad
Applications	Gears, bearings, rotary cutters, pins, bushings, links, shafts, cutting pliers, crankshafts	Bolts, knuckles, connecting rods, shafts, blades, barrels, pins, crankcases, links, gears, drill collars, tool joints	Springs, shafts, gears, wrenches, links, pins, screws, pliers, hammers, shovels, mauls, lock washers	Bearings, chisels, axes, razor blades, hand tools, saw blades, machinery parts, cutting steels	Equipment for high temperatures; equipment for low temperatures; sucker rods, staybolts

1941 to 1945 — War Period

From 1941 to 1945 all steelmakers' efforts were concentrated first on securing the maximum production of newer alloy steels to make the weapons

of war, and second, modifying steels so that the elements required would not exceed the elements available, even while attempting to produce as much as 15,000,000 ingot tons per year of alloy steel. This was accomplished by calculating leaner alloy steels to meet the hardenability of the more heavily alloyed steels they were intended to displace. This approach was successful, and the National Emergency or NE steels were devised. They included the 8000, 8100, 8200, 8300, 8400, and 8500 series of manganese-molybdenum steels and the 8600, 8700, and 9800 "triple-alloy", nickel-chromium-molybdenum steels. (Also included were triple alloys with higher manganese, NE 9400 series.) Steels of the Mn-Mo group were discarded in favor of the others, which continued in use throughout the war.

This program accomplished the desired effect in conservation as shown in Fig. 3. Chromium-nickel-molybdenum (NE) steels constituted about 25 to 30% of the total S.A.E.-A.I.S.I. alloy steel production during the war and went into many important items of ordnance. The NE steels which were considered most desirable then, the 8600 and 8700 series, predominate now and they still represent about 25% of the total grade mix, as shown in Table I, p. 492.

At this time it was reasoned that if hardenability could be used successfully to circumvent the difficult problem of changing steels without elaborate physical property tests, it must have value in specifications. A cooperative committee of A.I.S.I. producer members and S.A.E. consumer members laid plans to study hardenability frequency curves so as to establish hardenability band limits; as a result we have added to the S.A.E.-A.I.S.I. number the letter "H" to denote that the steel is furnished to hardenability requirements. This move solved numerous application and heat treating problems and has been another welcome advancement, permitting users to specify another quality requirement in alloy steel at no extra cost. Such a move could not have been made without an excellent background of research work on hardenability factors; this was the tool which permitted the job to be done speedily.

1946 to 1950—Consolidation Period

The effect of World War II, leaving behind it increased costs and high prices of raw materials and finished articles, caused still further interest in leaner alloy steels. Table I shows how this trend has affected today's product mix of alloy steels in America. Table IV extends this matter beyond chemical analysis to mechanical properties, and illustrates how economics has been affected by research to gain the desired ends of maximum production without impairing ultimate properties of the finished parts.

This is the reason why alloy steels of today cost less per ton to the consumer than like steels prior to 1920—they are better controlled and of higher quality and there is a better selection to fill the needs of an estimated 6,000,000 tons of S.A.E.-A.I.S.I. alloy ingots in 1950.

During the past four years the consuming and producing industries have been busy consolidating the gains made as the result of war experience. New grades of alloy steel or modifications of old grades, such as 4120 gear steels, 4100 modified spring steels, and S.A.E.-A.I.S.I. 5160 spring steels have been developed and adopted. During this period boron has been used somewhat more widely in intensifying the hardening action of the associated basic alloys in steels for basic tractor parts, bolts and diesel engine cranks.

The 1946-1950 period is classified as the consolidation period, but we predict something more than that will be said of the 1950 to 1960 decade.

Summary of Progress to Date

1. The alloy steel industry owes its production achievements thus far to the development of automobiles and experiences gained from wars.

2. The control, standardization, simplification, and development of new steels is attributed to the combined cooperative efforts of producers and consumers and technical representatives alike, and to the new lines of consumer industries that have sprung up since 1900.

3. Compared with other countries we have fewer and more economical basic varieties of alloy steels for like applications in different lines of industry.

4. We produce more alloy steel than all the rest of the world combined; our specification requirements are far more restricted than those in other countries, yet cost the American consumer no more than the looser requirements of his foreign competitor.

5. American technical groups have perfected a simplification and standardization in alloy steels unequaled by other countries.

6. By actual comparison with other countries' specification requirements, we know more about control of quality features, such as cleanliness, soundness, grain size, and hardenability, and we know how to apply these qualities where needed. We are much further advanced in heat treating techniques.

Without these accomplishments, it would have been almost impossible *(Continued on p. 562)*

Basic lined cupolas, synthetic resin binders for molding and core sands, centrifugal casting of thin-walled pipe, use of inoculants for both gray and nodular iron, improvement of working conditions and influx of engineering talent — all mean an era of increasing usefulness for iron and steel castings.

Ten Years of Advance in Ferrous Foundries

DEVELOPMENTS in housekeeping in the last decade have meant a great deal to the ferrous foundries in efficiency, quality, production and especially in the reduction of hard labor and increase in the comfort of the workmen. Ventilation, dust control, man-cooler fans, and air conditioning, along with appreciation and application of adequate illumination, have improved efficiency. Air conditioning of crane cages has done much for those fellows who work in the rising currents of hot air, hot dust, and steam over our foundry floors; it gives them better vision as well as an attractive job instead of an uncomfortable one. There is no trouble to get men to work in a well-lighted, well-ventilated foundry.

Melting has received much attention. Modern, high-powered electric furnaces give close control of analysis; likewise they are much easier on refractories for this reason: Most steel for castings is tapped at temperatures well above the softening point of the silica refractories, so the time necessary to give the steel its last few hundred degrees is of paramount importance — hence the need for ample power.

The oxygen lance has proved to be a valuable tool in steel melting and has enabled the melter to oxidize carbon preferentially to chromium — thus producing low-carbon stainless from all scrap without undue loss of chromium. The rapid determination of nickel and chromium by spectroscopic methods — ten minutes or even less — has permitted the use of all-scrap melts, cast direct without the necessity of pigging, analyzing, remelting and adjustment which was formerly the practice.

The cupola has been the subject of considerable research both here and abroad. Hot blast, dry blast, and balanced blast, while not new, have been rather extensively applied. Some promising results have been reported on water jacketed furnaces with scarcely any refractory linings. Oxygen-enriched blast has been found to increase melting rates (approximately in simple proportion to the enrichment) and standby oxygen supply is maintained in several foundries to use as medicine for short periods in case of trouble. Duplexing from cupola to air furnace has been adopted in some malleable foundries with excellent results.

Basic cupola linings are a very live subject, especially in connection with the production of nodular irons where low sulphur and high carbons are desirable. Some extremely interesting results when calcium carbide was substituted for limestone in a basic cupola were reported by Carter at the last American Foundrymen's convention: Sulphur of 0.025% and carbon 3.50% were obtained with an

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Birmingham, Ala.

all-steel charge, whereas acid practice using the same coke would have resulted in 0.100% or more sulphur and 2.75% or less carbon. While on the subject of basic refractories, some interesting results have been reported by Sims and Toy on a small basic bessemer* which gave acceptable dephosphorization of metal containing about 0.3% P — metal which has long been considered quite out of the range of the conventional basic bessemer.

Molding has become so highly mechanized that it is now difficult to train and almost impossible to find what was once thought of as "a molder". Sand is prepared in high-speed mullers to meet exacting physical specifications for moisture, strength, permeability, and other properties. Synthetic resins are used for binders for molding sands as well as for cores. These resins require none of the oxidation needed by the conventional core oils, hence the "drying time" is simply the time required to drive off moisture and heat the mass enough for the resin to flow. Drying times less than half that of oil-sand cores are usual with ordinary core ovens; when induction heat (widely adopted) is used for drying, minutes instead of hours are sufficient if enough power is provided.

The live topic of the moment is the so-called "C process", developed by Croning in Germany during the war. He uses a dry mixture of sand and a thermosetting resin, which gives a strong, permeable mold, as thin as may be desired and quite accurate to pattern. (Tolerances of a thousandth of an inch are claimed.) In the last 10 years ceramic investments have come into wide use for small castings, especially in highly alloyed metals, in the so-called precision casting methods. Beautiful castings are made to very close tolerances, as can be seen by the example pictured on the opposite page, so that no further mechanical treatment is necessary.

*Reference may be made to Dr. Work's article on the bessemer process for steelmaking, p. 519.

James T. MacKenzie

KNOWN affectionately as "Mac" or "Mr. Cast Iron" to fellow members in the American Society for Metals, American Foundrymen's Society, American Society for Testing Materials, the Electrochemical Society, and the American Institute of Mining and Metallurgical Engineers, JAMES MACKENZIE has spent his entire working life with the American Cast Iron Pipe Co., starting in 1912 as analyst, and in 1947 becoming a member of the board of directors. He graduated from the University of the South; he has served on its Board of Regents, and received from it the degree of Doctor of Science. The list of his contributions to the literature of foundry metallurgy is almost as long as the list of honors he has received from engineering associations here and abroad. He is Trustee-Elect.

Centrifugal Casting

Centrifugal casting had a wild ride early in World War II, when the shortage of forging capacity forced the use of castings for many parts. A typical example of successful substitution was the cast cylinder barrel for one of our big bomber engines. Many thousands of these barrels were centrifugally cast and the service records were entirely satisfactory. Gun barrels from 60 mm. to 150 mm. caliber were also cast — both heavy guns up to 18-ft. length and the light, short pack howitzer were cast in great numbers and met all the specifications. In contrast to these hollow shapes, many solid castings were made by "semicentrifugal" and "centrifuging" methods, wherein the mold itself was spun or fixed to a radius bar, but it was usually found that the spinning of the mold was of very little value since the principle of directional solidification had to be scrupulously observed to get sound castings and when that was done there was no need to spin the molds.

Following the war four or five new plants were built for making cast iron pressure pipe by the deLavaud process, supplanting either pit casting or green-sand on-side methods (both of which processes used too much man power at Fair Deal wages to be competitive). The same economic urge forced the soil pipe manufacturers to centrifugal methods. Some quite ingenious layouts have been made to achieve the speed necessary in casting (and in the sand cast methods, ramming and shaking out) these thin tubes. Centrifugal casting of bimetallic brake drums allows the combination of a tough steel backing and the excellent braking surface of a high-carbon gray iron. (Arthur E. Schuh of U. S. Pipe and Foundry Co. developed an excellent process for making bimetallic tubing, spinning a go-between layer of liquid slag which prevents oxidation of the inside surface of the first metal to be spun.) Centrifugal casting of high-alloy tubing seems destined to hold on, since it is ideal for

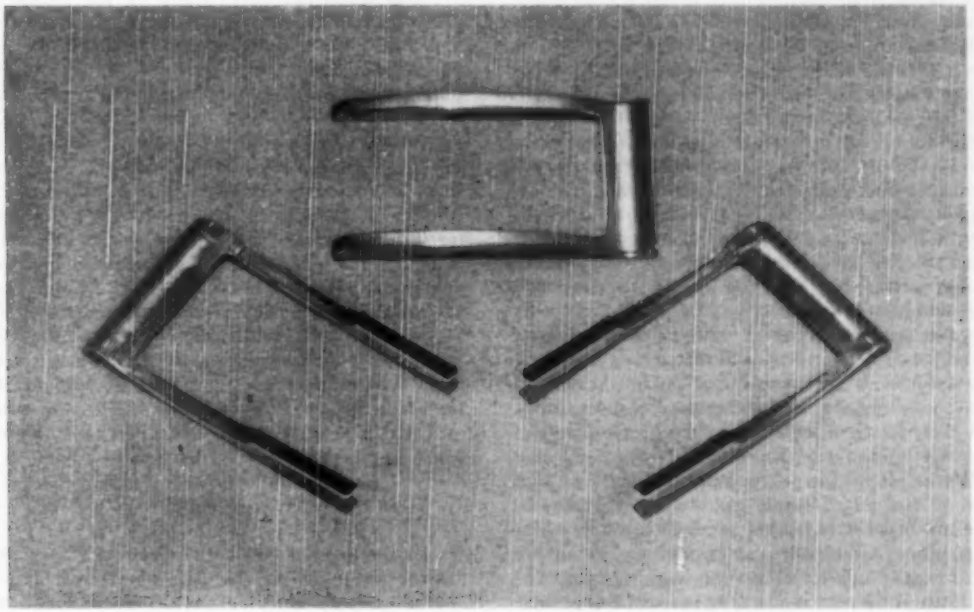
medium to heavy wall tubing in small lots — a very unattractive proposition for the tonnage steel mills. Furthermore, these high alloys are difficult to pierce on account of their high strength at high temperatures, yet their casting temperatures are generally lower than low-alloy steels.

Metallurgy of Castings

In the steel castings industry much valuable work was done in the study of fluid flow, in gating and risering, the use of riser compounds and blind risers, while the discovery of the cut-off core was a great saving in time and oxygen in the cleaning rooms. Metallurgically, some of the triple-alloy steels, low in alloy and known as NE constructional steels developed during the war, have retained a place in our specifications and their use has added much to our knowledge of the properties of steel.

In the metallurgy of gray iron, the use of inoculants has been widespread and of great value in the production of medium to high strength gray iron without chilled edges or fins which delay production by ruining tools. Furthermore, the stabilizing type of inoculant has enabled the foundryman to make castings with the very high carbon desirable for heat resistance and damping capacity without too much sacrifice in strength — the strength being raised in the pearlitic matrix sufficiently to compensate for the weakening effect of the increased graphite. The acicular irons have also been extensively developed; they give a valuable combination of strength, fairly high modulus of elasticity, wear resistance, and reasonably good damping capacity.

Nodular Iron — By far the greatest excitement in ferrous metallurgical circles since time immemorial was caused by the discovery by the British



A Spring That Is a Casting

Full sized views of spring clips for a hearing aid, as cast by Arwood Precision Casting Corp., Brooklyn, N. Y. Not machined, buffed or finished in any way. Cast of beryllium copper (nominally 2.0% Be, 0.5% max. Fe plus Co, balance Cu), heat treated by solution heating and aging, after casting, to Rockwell C-38 to 40 hardness. Dimensional tolerance of casting: ±0.005 in. per in. of width; minimum thickness 0.012 in. ±0.002 in. Required test for spring properties: Fix ends of arms horizontally. Load cross bar with 400 g. at each end. Maximum deflection 0.140 in. Cross bar to return to within 0.005 in. of its original free position after unloading.

Cast Iron Research Assoc. of "nodular" iron made by adding a cerium alloy to a hypereutectic iron, high in silicon and low in sulphur. This was followed by International Nickel Co.'s announcement that the same results could be achieved with either hypo-eutectic or hypereutectic iron by treatment with magnesium or magnesium alloys. The strengths attained in this material are truly phenomenal, accompanied by considerable elongation which is roughly inversely proportional to the strength.

Statements have been made that nodular iron is tougher than malleable, but as far as this writer can see the comparison has been made between nodular iron keel blocks and the standard malleable iron test bar (which is tested as-cast and after heat treatment). This is obviously unfair to malleable iron. However, the material does have interesting properties and will undoubtedly find its niche in the hall of ferrous metallurgy.

As far as its castability is concerned, the high-carbon irons are extremely fluid at ordinary casting temperatures, but the solidification shrinkage is approximately the same as white iron. On account of the tendency of fins to come out white, problems multiply in the cleaning shed. A combination of a white fin on an extremely tough casting tears up chisels by the bushel, and grinding wheels are almost as ineffective! In our experience, torch cutting is very risky, as the metal cracks badly. Welding of nodular and malleable is equally difficult; none that we have seen retains the ductility of the parent metal, except in a few simple shapes welded in a laboratory.

Strength properties of nodular iron are good but the damping capacity and insensitivity to notch effect — two of gray iron's most important characteristics — are poor. The corrosion resistance has not been determined but there is no reason we can see why it should be any different from malleable iron's. Cast iron pipe, for instance, owes a great deal of its reputation for long life under ground to the fact that the corrosion product is a dense mat of graphite flakes, iron oxides, and the phosphide eutectic, a complex with a compressive strength of well over 1000 psi. For example, a 6-in. pipe that burst at 600-psi. internal pressure showed, after sand blasting, a $\frac{3}{4}$-in. hole completely corroded through the $\frac{3}{8}$-in. wall! I do not believe the nodular graphite would have this binding power, and consequently such a pipe would have punctured years before. Wear resistance has been claimed to be good, but we tried graphitic steel for aircraft engine cylinders and found it poor, so I am personally dubious about it.

In the lighter vein may be mentioned the squabble about what to call it: The British started with nodular iron, but International Nickel Co.'s publicity has avoided that word like the plague, using "spheroidal" or "ductile". Pages of the technical press have been devoted to this somewhat childish argument which is still unsettled.

Inspection — Notable has been the application of modern inspection tools by all the foundries. X-rays, gamma rays, ultrasonics, Magnaflux and Zyglo have been quite extensively used for the final inspection of important castings, but have been even more important in determining the proper method of gating and risering all castings. Statistical methods of quality control have given good results, not only insuring a high level of quality in the product but eliminating much useless inspection and testing with consequent increase in production per man-hour.

Education

One important development of the decade of interest to all foundrymen is the establishment of the Foundry Educational Foundation. This is supported by the American Foundrymen's Society, the Foundry Equipment Manufacturer's Assoc., the Gray Iron Founders' Society, the Malleable Founders' Society, the Nonferrous Founders' Society, and the Steel Founders' Society. It has done a fine work in getting the colleges and universities of the country to take an interest in foundry training; through its scholarships, summer jobs, and permanent jobs for graduates it has attracted many fine young men to our industry who would never have known there were such places as foundries where engineering talent and training would be appreciated. Those mechanical, electrical, and other engineers who take these courses but go into design work will naturally be conscious of the properties of castings and their processes of manufacture when they begin to specify materials.

Conclusion

In summary it can be accepted as a fact that the revolution in the foundry which was started by the molding machine and by mold and sand handling conveyers — that is, the mechanical revolution — has been continued into the other phases of the industry. The variety of products and processes now available is impressive. Foundrymen and customers alike are better informed about the properties and the utility of castings. The modern foundry is by no means a poor place to work in. It all adds up to the fact that the American ferrous foundry industry is awake to its responsibilities, and competent as never before to discharge those responsibilities in the days ahead.

Present high-temperature alloys are limited by deficient ductility; future turbines operating at 1700° F. will require alloys based on chromium, molybdenum or titanium — or on pure molybdenum with an oxidation resistant coat.

Gas Turbine Alloys, 10 Years Later

IN ORDER TO DISCUSS the past and future of those high-strength alloys suited for service above maximum steam temperatures, it is well to start with their present status. Immediately, however, a dilemma is faced because the subject is so complex that a full discussion of the present would extend much beyond the allotted space, and a severely abbreviated presentation would lead to many misconceptions. A compromise is reached here by grouping the alloys in use today by types for purposes of discussion. With this apology for the anticipated shortcomings of a brief paper, a classification is presented at once.

Representative alloys are identified in Table I, grouped on the basis of available forms, namely, as wrought products (including bars and forgings) and as complex shapes obtained by precision investment casting. A few alloys are available in both, but the best composition for one method is not generally the best for the other.

Another classification, one not shown in the table, is based on intended application. All of the precision-cast alloys are intended primarily for rotating blade service at temperatures of 1350° F. or higher, as are most of the wrought alloys. Only the iron-base alloys, the first four, are clearly designed and used primarily for rotors and bolts where temperatures seldom exceed 1100° F. but stress requirements are high. Inconel X, a nickel-base alloy, is considered applicable in both categories.

It is clear from the compositions listed in Table II that all of these alloys are fully austenitic (except possibly 19-9DL in some conditions). The advantage of the face-centered cubic lattice over the body-centered for creep resistance has been recognized from an early date. Chromium content for oxidation resistance, however, is not particularly critical; in fact, Hastelloy B which contains none has served well as gas turbine blading up to 1400° F. Furthermore, chromium does not appear to contribute much to strength, so its content is determined chiefly by the oxidation resistance required. Unfortunately, sufficient data on oxidation resistance is lacking to permit valid comparisons on this basis. It is known, however, that carbon is antagonistic to oxidation resistance and must be compensated for by chromium additions more or less proportional to carbon content.

The typical "super" alloy, then, has a solid solution matrix of iron and chromium with at least enough nickel to provide a fully austenitic structure at room temperature, and with cobalt or nickel substituting for part, if not all, of the iron content. Such a solid solution alloy as-annealed is quite weak and has an inadequate yield strength when cold, or creep strength when hot. Useful strength is acquired by one means or another which can be broadly classified as chemical or physical. The chemical means are identified in Table II by three headings, Group I being the solid solution base elements having little effect on hardness. Group III are the obvious hardening agents of very low solid solubility. Group II is intermediate; the members have moderate solid solubility and therefore are more closely related to Group I when present in small amounts and to Group III when they are present in large amounts.

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Table I — Identification and Classification of Heat Resistant Alloys Finding Application Under High Stresses at Temperatures Over 1000° F.

Alloy Name	A.M.S. Spec.	Development Organization	Alloy Base	Hardening Agents		Temperature Rating*
				Chemical	Physical†	
		Available in Wrought Form				
Uniloy 19-9DL	5722A	Universal-Cyclops	Fe	C	HCW	1300 °F.
EME	5730	Midvale	Fe	C, N	CW	1250
16-25-6	5727	Timken	Fe	Mo, N	HCW	1350
Discaloy	5733	Westinghouse Electric	Fe	Ti	PH	1300
Inconel X	5668B	International Nickel	Ni	Ti	PH	1400
Hastelloy B	5752	Electro Metallurgical	Ni	Mo	ST	1350
K-42-B	—	Westinghouse Electric	Ni + Co	Ti	PH	1400
Refractaloy 26	5760	Westinghouse Electric	Ni + Co	Ti	PH	1500
Multimet (N155)	5768	Electro Metallurgical	Ni + Co	Mo, N	PH	1400
S590	5770	Allegheny Ludlum	Ni + Co	Mo, C	PH	1440
Refractaloy 70	—	Westinghouse Electric	Ni + Co	Mo	PH	1450
S816	5765A	Allegheny Ludlum	Ni + Co	Mo, C	PH	1550
		Available in Precision Cast Form				
Haynes Stellite 27	5378	General Electric and Haynes Stellite	Ni + Co	C, Mo	—	1450
Haynes Stellite 30	5380	General Electric	Ni + Co	C, W	—	1525
Haynes Stellite 31	5382A	Haynes Stellite	Ni + Co	C, Mo	—	1550
Refractaloy 80	—	Westinghouse Electric	Ni + Co	Mo	PH	1450
Haynes Stellite 21	5385	Haynes Stellite	Co	C, Mo	—	1400
Haynes Stellite 23	5375	Haynes Stellite	Co	C, W	—	1475

*Based on 100-hr. rupture life at 25,000-psi. load.
†Code: CW = Cold worked
HCW = "Hot cold worked"
PH = Precipitation hardened
ST = Solution treated

Hardening by excess compound formation is quite effective but of limited utility in the wrought alloys which must of course be forgeable. In all of these alloys in present use, some physical treatment is utilized for strengthening and hardening — either work hardening or heat treatment. For example, the first three alloys of Table I derive their useful strength largely from work hardening. This treatment is not the conventional cold rolling at room temperature because of the large sections required and also because their compositions were chosen for high initial resistance to deformation. The process actually used is called "hot cold working" — forging or rolling at elevated temperatures not high enough to induce recrystallization. This development was both timely and important, and is the subject of further attention in the section on history.

Most of the other wrought alloys are distinctly susceptible to precipitation hardening, their composition being chosen to provide a second phase of variable solid solubility with temperature. Hardness in the range 250 to 375 Brinell is attainable after a solution treatment at a high temperature followed by aging at a considerably lower one. Typical treatments are listed in Table III. Most of these alloys are low in carbon, since carbon lowers the response to aging as well as the characteristic aging temperature. Nevertheless, aging occurs rapidly in the relatively high-carbon precision-cast alloys at operating temperatures.

Still another classification is included in Table I — namely, a temperature rating which represents the average creep properties of the alloys. Too much weight is currently given to this criterion of merit without reference to ductility. Also the *minimum* in strength (or in any other rating) is the important property from the design viewpoint, but such data can only be acquired with use in some tonnage and therefore are quite scarce at present. Furthermore, we find apparent discrepancies: Refractaloy 80 is used effectively as a stationary member at temperatures around 2000° F. although the temperature rating given in Table I is 1450° F. That is possible because the tensile stress is relatively low, and the strength of this alloy does not decay rapidly with increase in temperature. More is said about this situation in the discussion of future trends.

The Past

For a reasonable estimate of the future, we must look closely at the past. This is one of our assigned tasks. We find quite uniformly that the history of most significant developments goes back

well before 1940. In fact, incentives for development of heat resistant alloys existed long before then. For example, it was recognized at an early date that resistance to softening at elevated temperatures is a requirement for high speed toolsteel. Also there was need for a heat resistant alloy for the exhaust valves of internal combustion engines.

Elwood Haynes obtained a patent in 1907[1] on an alloy which was the forerunner of the famous Stellite cutting tools as well as of some precision cast alloys. Fortunately in those days, a man could get broad enough coverage on his invention so that he had a gambler's chance of getting back his investment! Note Haynes' claim 1:

> "A metal alloy composed of a metal of the chromium group and cobalt."

Noteworthy also is the fact that he filed in April and the patent was issued in December of the same year. More about this interesting alloy family presently.

While incentives existed early in this century, the demand was not intense enough to justify the large expense required for rapid development. Only in the period around 1940 did these incentives become compelling. Extensive research and development were undertaken; the government also underwrote a great deal of work; progress was rapid. This work was aimed at the procurement of suitable alloys for two devices — first, the Moss exhaust-gas turbosupercharger, and later the turbojet aircraft engine. In this country, in fact, the former prepared a substantial background for the latter. The development of both devices is well described by Schlaifer and Heron[2] in their book "Development of Aircraft Engines and Fuels", as well as the contributions of alloys thereto. Our metallurgists may find some satisfaction from this direct quote from their book:

> "Thus, it simply cannot be maintained that inadequate progress in metallurgy was in any degree responsible for delaying the development of aircraft gas turbines in the United States. Alloys which were generally considered by American engineers to be superior to anything used by either the British or the Germans already existed in 1930 either in their final form (in the case of Hastelloy alloy B) or in a form which could have been quickly developed to yield the final form (in the case of Stellite alloy No. 6, which was developed into No. 21), and it was these alloys which were in fact used for the first American production turbines in the 1940's."

Table II — Nominal Composition of Heat Resistant Alloys

Alloy Name	Group I (Basic Elements)						Group II (Intermediate)			Group III (Hardeners)			
	Ni	Co	Cr	Fe	Mn	Si	Mo	W	Cb	C	N	Ti	Other
Uniloy 19-9DL	9	—	19	66	1.1	0.5	1.4	1.4	0.4	0.31	—	0.2	—
EME	12	—	19	63	0.5	0.5	—	3.2	1.0	0.15	0.15	—	—
16-25-6	25	—	16	51	1.0	0.5	6.2	—	—	0.08	0.15	—	—
Discaloy	26	—	13.5	54	0.8	0.8	3.2	—	—	0.03	—	1.6	0.1 Al
Inconel X	73	—	15	7	0.7	0.4	—	—	1.0	0.04	—	2.5	0.7 Al
Hastelloy B	66	—	—	5	0.6	0.2	28	—	—	0.08	—	—	0.3 V
K-42-B	42	22	18	14	0.7	0.7	—	—	—	0.03	—	2.1	0.2 Al
Refractaloy 26	38	20	18	16	0.8	1.0	3.2	—	—	0.03	—	3.0	0.2 Al
Multimet (N155)	20	20	21	30	1.5	0.6	3.0	2.5	1.0	0.12	0.15	—	—
S590	20	20	20	27	1.5	0.6	4.0	4.0	4.0	0.43	—	—	—
Refractaloy 70	21	30	20	14	2.0	0.3	8	4.2	—	0.04	—	—	—
S816	20	41	20	4	1.5	0.6	4.0	4.0	4.0	0.37	—	—	—
Haynes Stellite 27	36	30	26	1	0.5	0.4	6	—	—	0.42	—	—	—
Haynes Stellite 30	15	51	26	1	0.5	0.4	6	—	—	0.42	—	—	—
Haynes Stellite 31	10	54	25	1	0.6	0.7	—	7.5	—	0.50	—	—	—
Refractaloy 80	20	30	20	14	0.6	0.7	10	5	—	0.10	—	—	—
Haynes Stellite 21	2	64	26	1	0.3	0.6	5.5	—	—	0.20	—	—	—
Haynes Stellite 23	2	65	25	1	0.3	0.6	—	6	—	0.38	—	—	—

While emphasis is usually placed on alloy composition, *processing* is no less important and is related thereto. Two highly significant process developments were the "hot cold working" process (which induced the required strength in rotors of turbosuperchargers and jet engine turbines) and the precision investment casting process (which made turbine blades in quantity for both devices).

The "hot cold working" process was devised by Charles T. Evans at the Cyclops Division of Universal-Cyclops Steel Corp. during the early

[1]References are listed on p. 544.

Table III — Heat Treatment of Wrought Alloys (Bars and Forgings)

Alloy Name	Stress Relief		Solution		Aging		A.S.T.M. Grain Size	Brinell Hardness
	Temp.	Time	Temp.	Time	Temp.	Time		
Uniloy 19-9DL	1200° F.	4+ hr.	None		None		—	228-277
EME*	1200	4+	None		None		—	269-321
16-25-6†	<1210	4 hr./in.	None		None		—	235-293
Discaloy	None		1800° F.	1 hr.	1350° F. 1200	20 hr. 20	4+	248-302
Inconel X	None		2100	2 to 4	1550 1300	24 20	—	262-341
Hastelloy B	None		1900	24	None		4 to 8	210-285
K-42-B*	None		1750	1	1300	24	5+	269-341
K-42-B*	None		1950	1	1350	20	3+	221-302
Refractaloy 26	None		1800	1	1350	44	6+	302-375
Refractaloy 26	None		1950	1	1500 1350	10 20	3+	262-341
Refractaloy 26	None		2100	1	1500 1350	20 20	1+	241-311
Multimet (N 155)	None		2175	1	1500	4	—	193-241
S 590	None		2200	1	1400	10	—	248-331
Refractaloy 70	None		2250	4	1600	16	5+	293-352
S 816	None		2150	1	1400	12 to 16	1+	248-331

*EME and K-42-B bars. †16-25-6 forgings.

1930's, and was applied to their alloy 17W, whose typical composition was 20% Ni, 13% Cr, 0.7% Mn, 0.8% Si, 2.2% W, 0.6% Mo and 0.50% C. The immediate application was for both blades and disks for the Moss turbosupercharger then under development by the General Electric Co. Substantial production with 17W started in 1937 and continued until it was superseded in late 1941. Evans' hardening process, however, has since been in continuous use on 19-9DL and 16-25-6 and on allied alloys used in both turbosuperchargers and jet engines.‡ Since Schlaifer and Heron do not do so, it is pertinent to emphasize the fact that a strong rotor material is just as important as a good blading alloy even though the service temperatures are considerably lower. The size, shape and service requirements of the rotor are so much different from those of the blades that an entirely different approach is required.

The precision casting process played much the same role with respect to blading as did the "hot cold working" process to rotors. It too had its beginnings in the early 1930's (can there be a correlation with depressions?) when a process was being sought by the Union Carbide and Carbon Research Laboratories for casting stainless steel into intricate shapes, the immediate objective being ornamental castings. Investment casting was at that time an old art, known as the lost-wax process, and was applied to the relatively low-melting gold alloys employed in dentistry and bronzes for statuary. What was needed was an investment material that would withstand the high casting temperatures of iron-base alloys. Eventually, in 1936, a patent issued to Arthur B. Ray of that laboratory covering a mold made of refractory sand bonded with silica in colloidal form derived from the hydrolysis of an organic silicate.[3]

The market for cast stainless ornaments, however, was disappointing and the process remained on the shelf until the dollar was devalued and a substitute for noble metal dental appliances became a matter of concern. With this incentive, Charles H. Prange and Albert W. Merrick of the Austenal dental laboratories sought such a casting process and a noncorrosive alloy to be used with it. They found a casting process at the Union Carbide and Carbon Research Laboratories and an alloy at the Haynes-Stellite Division of same corporation. The alloy was a modification of Haynes Stellite Alloy No. 6 (now their No. 21) and which is called "Vitallium" by Austenal.

This alloy was of course a direct descendant of the binary cobalt-chromium alloy Haynes patented in 1907. While not intended for hot strength, it was found to be exceptional when Haynes Stellite No. 6 was tested by the maker in 1930. Turbo-

‡For splendid cooperation in providing much historical information not available in published papers, the writer gratefully acknowledges the contributions of Frank Garratt of Universal-Cyclops Steel Corp., Russell Franks of the Electro Metallurgical Division of Union Carbide and Carbon Corp., and Charles T. Evans, Jr., of the Elliott Co.

supercharger blades were cast from it in 1933, but the investment casting process had not yet been sufficiently perfected for so large a size to stringent physical requirements. Not until 1941 were the casting problems overcome and the composition modified to meet turbo requirements. Somewhat later, because of its superior strength and adaptability to quantity production, precision cast Haynes Stellite No. 21 blades went into the production of the Moss turbosupercharger.

From this start still other allied compositions were developed primarily for precision casting with advantages in one way or another over their predecessors. One was used in part of the production of the Westinghouse 19B jet engine (now the J30) and others are in use at the present time. Thus we unavoidably pass from the discussion of production processes to that of alloy compositions.

The acceptance of precision cast alloys for turbo blades was not without rivalry from wrought alloys. Attention was focused on Hastelloy B in 1936 when its hot strength was found higher than Cyclops 17W's. Again we see that a material developed chiefly for corrosion resistance has useful hot strength. Again the development dates back prior to 1930. (Original work on this family of alloys was done by Becket and Franks at the Union Carbide and Carbon Research Laboratories around 1926.) Hastelloy B naturally was quite resistant to deformation and indeed all movement at high temperatures, but a practical forging process for turbo blades was developed by the General Electric Co. and was used for the production of blades in 1941.

The finer grain size of the wrought metal was a favorable point, but this process and alloy were eventually superseded by precision cast Stellite No. 21, partly because of limited forging capacity in wartime. Thus, production requirements appear as a major factor in the choice of an alloy composition and its method of fabrication. The real merit of the wrought blade did not emerge, however, until later in the development of the turbojet engine — as will be discussed presently, in connection with postwar research.

Howard Scott

WHEN SCOTT went to work at the Bureau of Standards (in his teens) he was fortunate in being associated with PAUL D. MERICA and R. G. WALTENBERG — the junior member of a team that studied the mysterious behavior of duralumin and came up with a workable hypothesis of age hardening. Thus he was thoroughly grounded for his work at Westinghouse, starting in 1925, especially the development of alloys hardened with titanium, described briefly in this article. He also is responsible for Kovar, a metal-to-glass sealing alloy.

Returning now to rotor alloys, still with reference to the turbosupercharger, the Timken Roller Bearing Co. had its alloy 16-25-6 under development in 1940. This alloy too dates back to an earlier composition patented in 1938, namely, 16-13-3.[4] In late 1941, it displaced Cyclops' 17W which, however, was neither the original nor terminal alloy in another family started in 1918 by Evans as Cyclops 17A and having the typical composition: 19.8% Ni, 7.5% Cr, 1.2% Si, 0.75% Mn and 0.42% C. Prior to the development of present stainless grades this alloy was used for submarine periscope tubes, needing a combination of strength and corrosion resistance. Alloy 17W was developed in a deliberate effort to improve high-temperature strength. The same is true of Uniloy 19-9DL (Table II) which followed, and its antecedent 19-9WMo. The latter alloy was used in the Houdry gas turbine manufactured by Allis-Chalmers, and the former supplanted 19-9WMo in diesel engine turbosuperchargers manufactured by the Elliott Co.

Any account of alloy contributions to turbosupercharger developments would be incomplete without reference to the Wright Aeronautical Corp. unit, a rather complete description of which was published in *American Aviation* in 1945.[5] It was designed to operate on gas at 1700° F., and its rotating blades were of the Westinghouse alloy K-42-B. The blades were air cooled, but blade temperatures were still high — about 1450° F. as determined by hardness tests of blades from service. (Precipitation hardening alloys attain a stable hardness directly related to mean temperature and time; temperature distribution may also be evaluated by this characteristic. The intricate hollow blade could not be precision-cast at that time — and possibly not even now — so a wrought alloy was mandatory. The alloy had to withstand several severe cold forming operations, including one across the grain which was very effective in disclosing nonmetallic inclusions. This situation required an intensive study of the control of nonmetallics in titanium hardened alloys while meeting production commitments. Progressive improvements in melt-

ing and casting details as well as composition control prepared a foundation for further exploitation of this valuable family of alloys which provides a combination of high-temperature strength with forgeability that is inferior to none.

Titanium hardened alloys date back to 1929 at least, when a patent application was filed by Pilling and Merica[6] of International Nickel Co. Later this company developed the heat resistant composition Inconel X.[7] A patent on the Westinghouse alloy K-42-B was issued to Halliwell in 1935.[8] Other compositions were developed abroad, namely, Nimonic 80 by the Mond Nickel Co. in England, and Tinidur by the Krupp interests in Germany, the former being a nickel-cobalt base and the latter an iron-base alloy. Both were used in rotating turbojet blades, the latter alloy necessarily in air cooled blades made by cold forming — another concession to production demands. Despite the low alloy content of the blades in the German jet engines, planes powered by these engines made an impressive showing when first used against the Allies.

Though the domestic development of turbojet engines and planes lagged behind Europe's, the turbosupercharger program had accumulated invaluable experience in production, immediately available for the turbojet demand. The first such engine built in this country, the General Electric I-A (an American version of the Whittle engine) flew in October 1942 with Hastelloy B blades. The first engine of purely American design, the Westinghouse 19B or J30, first flew as sole motive power for a plane in January 1945 with K-42-B blades. Later, Haynes Stellite Alloy No. 23 was substituted for the K-42-B of the Westinghouse engine, and Stellite No. 21 in the General Electric's. The need for production was largely responsible for this switch to precision cast blades during the war. This primacy of cast alloys, however, has since been challenged, postwar conditions being more favorable to a re-evaluation of the blading problem. In some engines, forged rotating blades were found to be definitely superior, and some forged S816 replaced cast blades late in 1947. Evidently the past healthy competition between both alloys and processes will continue into the future.

While the cast alloys won the battle for turbojet engine blades here during the war, the titanium hardened Nimonic retained acceptance in England, and Inconel X and K-42-B found use in bolts and other components. In the meantime, development work on two other members of the family was continued by Westinghouse. One, Refractaloy 26, was intended for a blading alloy with properties superior to K-42-B. Extensive data have been accumulated on its mechanical properties as affected by test temperature, hardener content and solution treatment which are summarized in Fig. 1. Its composition and heat treatment can be adjusted to obtain an exceptionally high endurance strength (closed circles) with little loss in the creep strength (open circles) attainable in the coarse-grained condition after 2100° F. solution temperature. The high endurance strength is particularly desirable

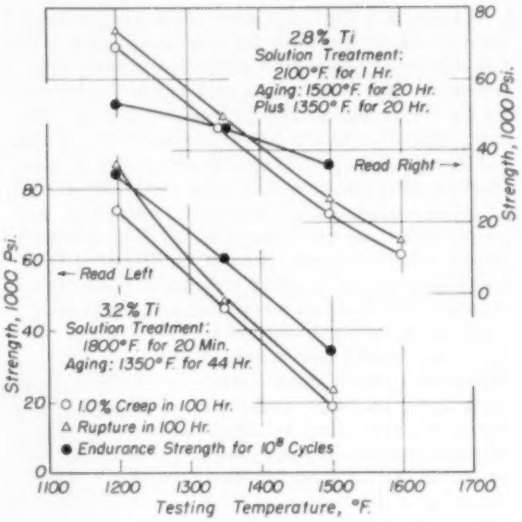


Fig. 1 — Composition (Especially Titanium Content) and Solution Treatment of Refractaloy 26 May Be Adjusted for Exceptionally Good Properties at High Temperatures

in second-stage blades where temperatures are lower yet vibratory stresses higher than in first-stage blades.

The titanium hardened alloys, however, appear to be even better adapted to rotors than to blades, and that was an early objective of work in this field which received additional impetus with production experience in blading. Here arose complex problems involving grain size control and the fabrication of large disks so as to permit complete recrystallization — a condition essential to uniform properties in the composition selected ("Discaloy"). High ductility was achieved by adjusting composition and heat treatment so that the notched bar strength under constant load at 1200° F. is at least equal to the unnotched rupture strength (U. S. Patent 2,519,406).[9] Ductility as measured by elongation at rupture on creep test at the temperature of minimum ductility is then much higher than in

blading alloys. Spin tests have shown that this material gives warning of impending failure by movement, even though its creep strength is still exceptionally high. Sufficient production heats have been made and tested to establish standard distribution curves which are used in the next section to illustrate one of metallurgy's major unsolved problems that will undoubtedly occupy more of our time in the future than in the past.

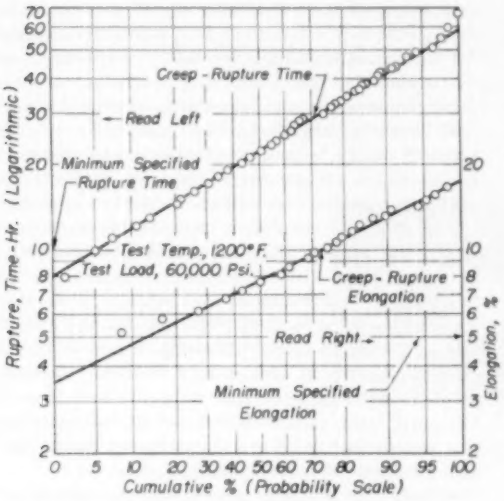


Fig. 2 — Statistical Distribution of Creep-Rupture Time and Elongation for Discaloy Forgings for Gas Turbine Disks From 150 Production Heats. (E. F. Losco, Westinghouse Materials Engineering Dept.[10])

The Future

Much experience gained on old alloys will be applicable to new ones; for example, the general relations already established between grain size, creep strength, ductility and fatigue strength will undoubtedly hold for new systems. Unfortunately, however, work on the old ones is far from complete so attention is directed first to the obvious problems requiring immediate attention before mentioning the more visionary challenges.

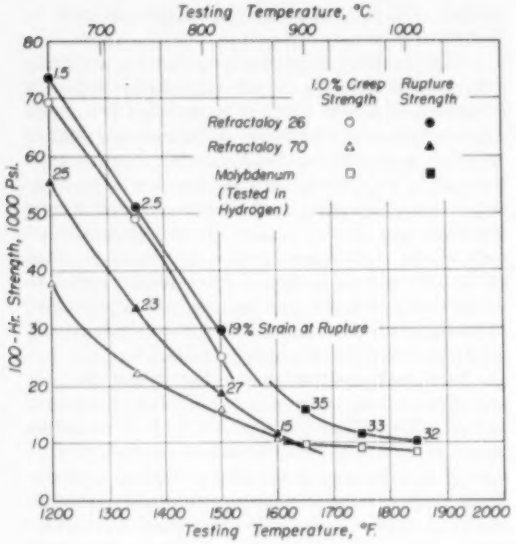
At the head of the list is the production of alloys with reduced spread or range in essential properties whose minima are specified. Even without changing the *mean* value of strength, the *minimum* strength of an alloy (which is that of most concern to the designer) can be increased by reducing the spread in values between successive heats or lots. However, neither producer nor consumer can afford to do this merely by closing the specification limits, for that only reduces the percentage of heats made by a standardized practice which can be shipped, and correspondingly increases production costs. What is needed is the identification of major factors responsible for scatter, so that appropriate controls can be instituted.

This problem is well illustrated by the creep test data in Fig. 2 of 150 production heats of Discaloy. A linear relation is obtained for creep-rupture time and elongation when data are plotted on a log scale against cumulative per cent of total tests on a probability scale. Our basic problem is to reduce the slope of this curve without lowering the mean or 50% value. It was thought that part of the scatter represented by the high slope of the two curves is due to unavoidable variation in hardener content, recognized by the specified titanium range of 1.35 to 1.85%, but this is doubtful from the following considerations:

Scott and Gordon[11] have shown that there is a normal inverse relation between rupture strength and ductility when hardener content is varied in alloys of this type, and it is known that rupture time at a given load is directly related to strength. With the data available, a reasonable relation between rupture time and elongation at rupture can be found and it has been used to correct all of the rupture times to equivalent values for an arbitrary elongation of 10%. These corrected values, however, fail to show any material improvement in the distribution when hardener content is eliminated as a variable. Evidently, then, a major cause of variation is not the normal variation in hardener content, but some other as-yet unrecognized factor or factors. Assiduous work will be required to identify it or them, both in the laboratory and production shop.

Since it has been shown that ductility is inversely related to strength when hardener content is varied, it is clear that this property, ductility, is as important as strength. We need to know, therefore, how far ductility can be sacrificed in the interest of improving the strength of a given alloy type. Apparently nature limits us quite definitely, since creep-rupture strength reaches a maximum when elongation is about 2% and thereafter diminishes with ductility. Gas turbine blades perform quite well, at least when vibratory stresses are not high, at this ductility level. There are complications, however, because ductility varies considerably with test temperature. In fine-grained titanium hardened alloys, it reaches a minimum in the 1100 to 1400° F. range. If the application involves a maximum temperature of 1500° F. where the alloy's ductility is obviously adequate, what are the ductility requirements at the temperature of minimum

Fig. 3 — Creep-Rupture Tests on Pure Molybdenum, Refractaloy 26 and Refractaloy 70, Show That the Pure Metal Has Better Properties Than the Alloys at Extremely High Temperatures. (Benjamin Lustman)



ductility? Certainly future work will provide an answer to this question, but possibly not until our knowledge of flow and fracture at high temperatures is considerably improved.

The precision-cast alloys and other coarse-grained alloys present still another situation: Their ductility is usually a minimum at room temperature, though obviously adequate at service temperatures. Presumably their hot strength could be increased by sacrifice of cold ductility, but how far can one go? This question is fairly well answered by shop experience, since the part must be able to withstand the abuses encountered in the shop, including grinding, without cracking. In fact, some compositions without measurable cold ductility by tensile test have withstood shop handling and fabrication, but these alloys were found to have observable ductility in the torsion test.

The point of these observations is that the strength or temperature rating of present conventional alloys may be improved by an increase in their hardener content if their ductility can be simultaneously increased by some expedient. Refinement of grain size is one such expedient; it has already increased the fatigue strength of Refractaloy 26 (but not without some loss in creep strength). Another means previously demonstrated[11] is the addition of molybdenum or tungsten to a titanium hardened alloy. Duplex aging of titanium hardened alloys has also improved ductility. Certainly future research should endeavor to uncover other means.

It is evident from the foregoing discussion that our present means for comparing alloys, particularly those from different families, leaves something to be desired. Certainly comparisons based on strength alone are inadequate, even when minimum values are available, since the alloys in question may not have the same ductility. Moreover, no satisfactory convention has ever been adopted for measuring ductility. Secondary properties such as forgeability, machinability and content of strategic elements are also important. These comments will possibly highlight the complexity of the research worker's task, and indicate why new and useful alloys for gas turbine service do not click off the production line with monotonous regularity.

Despite the remaining unexploited means for improving present alloys, the feeling is prevalent that they must fail to meet the requirements of the coming gas turbine era, namely, a service temperature of at least 1700° F. without any reduction of the stress level. Thinking is now in terms of combinations of new metals of higher melting point, as outlined very well by Parke and Bens.[12] The only such metals now available in quantity at a permissible price are molybdenum, chromium and titanium. What are the prospects?

Work has already been done on chromium-base alloys[12] which indicates that the desired properties are approached at 1700° F. in the cast condition. Room-temperature ductility, however, is very low, and it is still doubtful that their high-temperature strength would be superior to that of some conventional alloy if the hardener content were adjusted to yield the same cold ductility. Nevertheless, some of these chromium alloys could be hot worked, in which condition their ductility should be much improved. A comparison of mechanical properties of wrought chromium-base alloys with present alloys at both room and elevated temperatures should lead to a more satisfactory evaluation of the former.

Chromium is a borderline metal for demonstrating the presumed advantages of a refractory base since its melting point is only 620° F. above that of nickel, the most fusible member of the iron group. Molybdenum is better in this regard, melting 2100° higher than nickel, but on this account it cannot be melted and cast by conventional means! Nevertheless, it is available in the wrought form after consolidation either by powder metallurgy techniques or, more recently, by "arc casting" as developed by Parke and Ham of Climax Molybdenum Co.[13] Although there are no published

data on the high-temperature strength of the alloys, there is considerable available on the mechanical properties of molybdenum (for example, *Metal Progress* for August 1950) which is indicative of the alloying problem. Molybdenum also has the same body-centered cubic crystal structure as chromium and is in the same column of the periodic table, so much information would be interchangeable by analogy. Active development work on this metal is progressing in at least three laboratories and the results thereof are gradually becoming available.

Creep-rupture tests on pure molybdenum were made several years ago by Benjamin Lustman of the Westinghouse Research Laboratories. Results are shown in Fig. 3 along with comparative data on two representative heat resistant alloys. As expected, the creep and rupture strength for the pure metal is low, but it does compare very favorably with that of the alloys when above 1600° F. This is perhaps the first conclusive evidence that there is a material advantage to be gained by the use of a base metal with a high melting point in the design of a heat resistant alloy.

It is properly assumed that creep strength may be greatly increased by alloying, but there are two serious difficulties that must first be surmounted. For one thing, molybdenum forms a low-melting and highly volatile oxide which rapidly consumes the metal when exposed to air hotter than 1460° F.[14] The obvious addition to prevent oxidation is chromium, and chromium is soluble in molybdenum at all concentrations. Also Kessler and Hansen[15] have shown that it confers substantial resistance to oxidation. However, no one has yet been able to hot work molybdenum containing an effective chromium addition whether made by the arc-casting or powder metallurgy process! A wrought, oxidation resistant alloy may nevertheless emerge from the extensive work now under way. Such an alloy would undoubtedly have better creep resistance than the pure metal.

However, solution of the oxidation problem will not assure a useful alloy. Pure molybdenum has the reputation, though undeserved, of brittleness at room temperature; hardening by alloying is not likely to improve its ductility. Again we have ductility intruding as a major factor in alloying. Molybdenum breaks at room temperature with cleavage fracture; nevertheless, pure metal can be put in a highly ductile condition by a strictly laboratory operation. Still another difficulty with molybdenum, related primarily to its high melting point, is alloying with the more volatile metals such as manganese and chromium.

It is already quite clear that a body-centered cubic, heat resistant alloy will have to be used in the wrought condition if it is to meet even the present low requirements as to ductility. These metals will also be relatively expensive, either from raw material cost or from difficult fabrication. In order to conserve metal, closed die forging is indicated but, because of their intended high resistance to deformation, present die materials will be entirely ineffective. Some revolutionary changes in the art of metal forming are obviously necessary to handle the 1700° F. alloy before it can be manufactured commercially.

The remaining metal of great promise is titanium. It has a considerable advantage over others for rotating engine members in its low density — approximately 60% that of steel. It has exceptional corrosion resistance as well. Titanium is available now in some quantity as a fairly pure sponge, but here the catalog of favorable characteristics ends. Although its melting point is only slightly above that of chromium, conventional melting and casting techniques cannot be used because of its intense chemical activity; it must be isolated from hydrogen, nitrogen, oxygen and other nonmetallic elements except at quite low temperatures. Also its hexagonal crystal structure introduces directional characteristics that must be controlled. Nevertheless it is finding immediate application in the hitherto unfilled gap between the aluminum-base alloys and steel, and intensive work is under way on titanium alloys.[16]

Closure

This review may now be closed with the safe prediction, based on the history of alloys accepted at present, that the development of new ones based on refractory metals to a stage of industrial utility will be long, arduous, expensive and replete with disappointments. On the other hand, those closely associated with it will find themselves faced with a fascinating series of provocative problems that more than offset the tedious phases of normal research and development. If these problems are attacked realistically and with enthusiasm by those committed to their solution, the resulting accomplishments will make intensely interesting reading 10 years hence.

Wartime production of castings to rigid quality specifications gave magnesium the name of a high-priced metal. Postwar developments in many directions have removed this stigma. Today commercial uses require twice as much tonnage as the military uses. Ample productive capacity and technical skill insure rapid expansion of capacity in an emergency.

A Review of Productive Capacity in the Magnesium Industry

IT IS COMFORTING to record that the capacity of the magnesium industry to produce, and the ability to expand to meet a new demand in 1950, is in sharp contrast to the situation 10 years ago. In 1940 very few facilities or people had ever been engaged with processing or using magnesium. The intervening five-year period of wartime expansion and military business and the five-year period of peacetime commercial developments have had their strong effects on the present situation and its potentialities.

Let us briefly review the history:

In the World War I period, magnesium powder was primarily useful as an ingredient for pyrotechnics. During the peacetime years up to 1939, magnesium became truly an infant commercial industry; total production in 1939 was 3350 tons, and U. S. consumption only a fraction of this. Magnesium castings were used for aircraft wheels and engine parts, but the aircraft industry was small. A small entry had been made into portable tools and textile machinery. Magnesium die castings were used for a few automobile parts. However, only pilot-plant quantities of wrought magnesium (sheet, extrusions, and forgings) had been used by American industry.

In World War II, aircraft was the largest user of magnesium; next was the incendiary bomb. Another major item was an alloying agent in the greatly expanded aluminum industry. Wrought magnesium parts were still negligible. America's entry into World War II demanded an almost 100-fold increase in ingot production; annual capacity was increased to 293,000 tons and the country's demand was met in 1943, though magnesium was critically short up to then. Foundries were built rapidly enough to keep up with the ingot supply.

At the end of the war, most military orders were cancelled, and all ingot plants shut down — both because there was little peacetime demand and because there were large amounts of war scrap available. The commercial industry was almost in the position of starting all over again, at the bottom — at least after the first year or two of war-created shortages of all metals was satisfied. Since 1947, demand has steadily risen, most of the excess scrap has been used, and one of the ingot plants is now producing at a rate of 22,500 tons per year.

A basic change has taken place in this second five-year period. Whereas previously wrought magnesium was negligible, the quantities of sheet and extrusions have increased until the monthly wrought magnesium production now exceeds castings. (See Fig. 2.) Advances in production technology and intensive work in service design have

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uncovered many new uses both in military and commercial fields.

In the form of large, complicated, high-quality, and rigidly inspected sand castings for aircraft, magnesium developed a reputation for being an expensive material, and was used primarily where lightness was worth a premium. Recent increases in commercial use is due in large part to cost reductions. Many forms, such as extrusions, plate, or die castings, are now as cheap *per part* as aluminum or zinc. Therefore magnesium is no longer viewed simply as a premium material. Compared with a general inflation of about 75% since 1940, as shown in Fig. 3, p. 514, magnesium prices have in some forms advanced approximately

10%, but in others have held firm. This big change in relative costs should have resulted in a greater expansion of the magnesium market, except that its principal competition is from aluminum, and the aluminum industry has also been able to combat inflationary trends.

The following sections will describe these 10-year advances in more detail.

Ingot Production

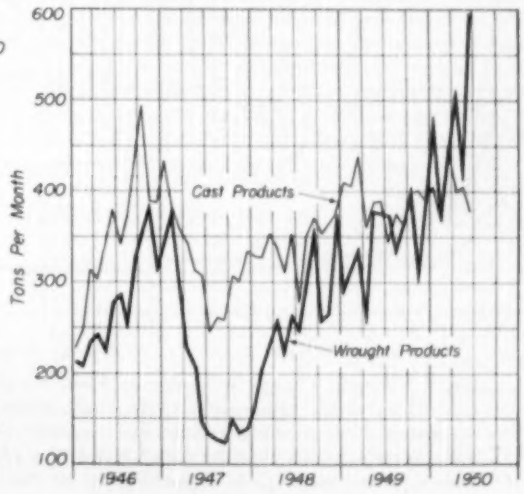
In 1940, all American ingot came from the electrolysis of magnesium chloride extracted from underground brines at Midland, Mich. In January 1941, Dow Chemical Co. put a seawater plant into operation at Freeport in Texas. Here lime added to seawater precipitates magnesium hydroxide, which can then be converted to magnesium chloride and electrolyzed in the usual way.

As with aluminum, the prime factor involved in ingot production is electrical power, an over-all input of about 9 kw-hr. per lb. of magnesium being required for the electrolytic process. Available power is more nearly the determining factor in the country's capacity to produce magnesium than it is the determining factor in aluminum, since magnesium ores of various kinds exist in great abundance and are widespread. Furthermore, magnesium exists in practically infinite amounts in the ocean: It has been figured that if magnesium were extracted at the rate of 100 million tons per year for a million years, the concentration in the ocean would have dropped from 0.13 to 0.12% — if no more magnesium had been washed into the ocean in the meantime!

However, other factors guided the wartime expansion: The apparent simplicity of chemical reduction processes encouraged many attempts to

Fig. 1 (Left) — Amount of Primary Magnesium Produced and Sold in the United States, 1925 Through 1950 (Estimated). From data published by U.S. Bureau of Mines

Fig. 2 — U.S. Shipments of Cast and Wrought Magnesium Products Since 1946. Monthly production of wrought products has recently exceeded castings. In this pre-Korean period, magnesium wrought products are primarily for commercial uses, while sand castings are primarily for military aircraft. Data from U.S. Bureau of Census



reduce magnesium oxide with carbon or with active metals such as silicon, aluminum or calcium. Six of the plants built by the Government in the early 1940's were based upon such chemical processes. They were smaller and later in construction, so the bulk of the ingot was electrolytic; nevertheless, these chemical or thermal reduction processes would probably play an important part in any future emergency, for reasons which will be brought out.

The reaction $MgO + C \rightarrow Mg + CO$ proceeds to the right at about 3600° F. and low pressures, but the mixture of metal vapor and carbon monoxide must be "shock quenched" to prevent reversal of the reaction. Shock quenching with large volumes of hydrogen or other gases has been tried on a commercial plant scale in Austria, Korea, England, and California, but failed because of the practical difficulty of recovering the finely divided magnesium dust. Other pilot plants in the United States trying this so-called Hansgirg process were based upon shock quenching with oil or molten lead — or just condensing the magnesium vapor upon a cold surface — but none of these was economically successful.

Several plants were built, however, based upon the thermal reduction of magnesium oxide with silicon. In this reaction, which proceeds at temperatures of about 2100° F. and low pressure, magnesium vapor is the only volatile product, so it can be easily conducted away from the reaction zone and condensed. In practice, 75% ferrosilicon is the reagent and calcined dolomite is the ore, since it is widely available and since calcium silicate is a convenient residue which also facilitates the reaction. The reaction upon which the commercial plants were based is therefore

$$2\,CaO \cdot MgO + (Fe)Si \rightarrow 2\,Mg + Ca_2SiO_4(Fe)$$

While the six plants of this sort in the United States are now in stand-by condition, the Haley (Ontario) plant in Canada recently reopened.

One of the limitations of this reduction method — ordinarily known as the Pidgeon process — is that, as a batch process, the labor costs are quite high. If the retorts are operated as a continuous process, the charge freshly fed to the reaction zone gives off gases which interfere with efficient condensation and recovery of the magnesium vapor evolving from the outgassed part of the charge. Consequently, most of the war-constructed plants used externally heated chromium-nickel-iron alloy retorts about 10 in. in diameter and 10 ft. long, giving about 50 lb. of magnesium per charge. One successful plant used a much larger retort, internally and electrically heated, yielding about 500 lb. of magnesium per batch.

One of the advantages of the ferrosilicon thermal reduction process is that the over-all electrical power requirement is less than 5 kw-hr. per lb. of magnesium, since the retorts can be fuel heated. The plant can be placed at a convenient location for fuel and dolomite, and the 75% ferrosilicon (which requires the electrical energy for its production) can be shipped in from another region where power is available. The plants can also be built in small units — 10,000,000-lb. annual capacity — and so require no major labor movements.

Wartime electrolytic plants were widely spread throughout the United States and worked with various ores and processes. The two Michigan Dow-process plants electrolyzed magnesium chloride which was processed through several drying steps after extraction from

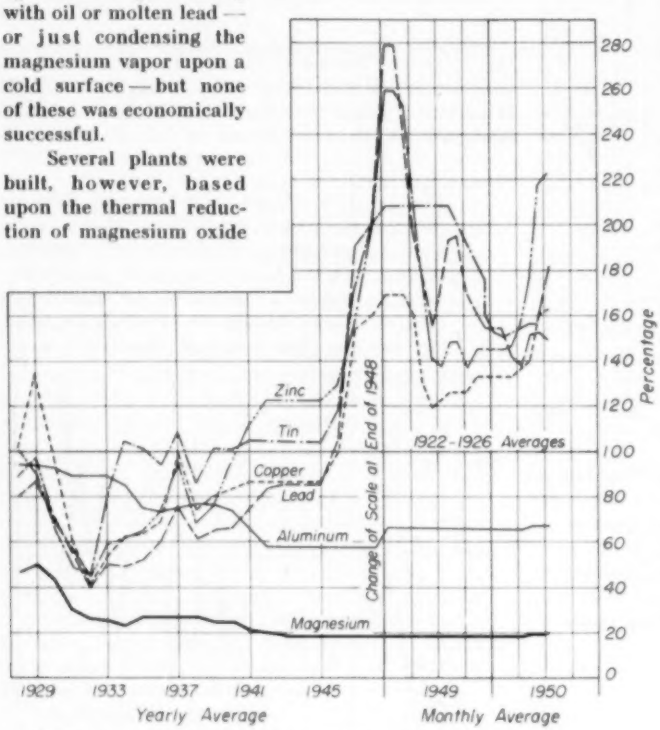


Fig. 3 — Relative Change in Nonferrous Metal Prices From a 1922-1926 Average. Prices of the light metals, aluminum and magnesium, in contrast to the others, have remained remarkably stable in the five years since the end of World War II. (Magnesium prices became f.o.b. shipping point on Dec. 1, 1947)

brine pumped from wells. The Painesville, Ohio, plant used the same process except that the source of the magnesium chloride was dolomite treated with byproduct liquors. The Dow-process Texas plants at Freeport and Velasco used seawater. A third Texas plant at Austin used the Dow electrolytic process with dolomite as the source of the magnesium.

An entirely different electrolytic process was operated at Las Vegas, Nev. Here calcined magnesium oxide was chlorinated to anhydrous magnesium chloride in an electric furnace by a method originated in Germany. Still another electrolytic process plant was constructed at Lake Charles, Louisiana, using dolomite as the source of magnesium.*

Considering the fact that many of these plants were using methods never before operated on a production scale, it is notable that most of them produced metal successfully. The experiments carried out resulted in a wealth of information which could not have been obtained other than from full-scale operation. Many of the wartime plants, now idle, were built at wrong locations. It is important that any future expansion of magnesium ingot capacity be at locations and by processes which will permit competitive operation in peacetime.

At the start of the last war, in 1940, very few facilities or trained personnel existed for fabricating magnesium, so that ingot was not immediately needed. In any future national emergency one must assume that the demands for ingot would pyramid very quickly. It is comforting to know that today we are in a vastly better position to face such a contingency.

J. Donald Hanawalt

ASSOCIATED with Dow Chemical Co. since 1931, first as a spectrographic expert, but soon in charge of metallurgical research which changed magnesium production techniques from small-scale operations to large, continuous processes, economical of labor and materials. In 1943 he received the Institute of Metals' annual award for his studies into the corrosion resistance of magnesium and its alloys.

Mill and Shop Practice

Sand Castings — In the war period, 1940 to 1945, most magnesium went into sand castings for the enlarged airplane program. New foundries were built, and many iron foundries converted. Foundry "know-how" was shared generally, and resulted in a large personnel with experience, so that the productive capacity for magnesium sand castings could be much more easily expanded now than it was in 1940.

Many of the basic technical problems received a great deal of attention, not only from the active foundries, but also from research institutes. Alloy compositions were evaluated from the standpoint both of service and castability. Porosity and weldability of the Mg-Al-Zn family as a function of zinc content were worked out in detail, and the results are now well known in the art. Grain size control was a major technical problem; it has been investigated and worked upon continuously throughout the whole 10-year period. At the present time, various carbon-containing reagents are used, as well as superheating and other treatments, but the fundamentals of the process still remain mysterious.

Permanent mold and die-cast parts in magnesium were used in limited amounts in military applications during World War II. Their commercial applications have developed slowly but steadily since 1945.

Sheet and Plate — In the 1940 to 1945 period, sheet was rolled in three or four small mills in the United States, but the total production was at most a few million pounds per year, and the sheet was used only in specialty items. The cost was relatively high because of the manual processing used. Only if a modern continuous rolling mill were available could the cost of magnesium sheet be lowered significantly, but such a large investment was not warranted by the market demand. After the war only one of the magnesium rolling mills remained in operation, and in the first postwar year about the only product was $\frac{3}{16}$-in. plate for magnesium griddles, a newly introduced item.

In the summer of 1946, pilot plant tests on continuous rolling were made by Dow at the American Rolling Mill Co.'s mills at Butler, Pa. — the original tandem mill in the United States. The

*Data on all of these plants giving investment costs, time of construction and costs of operation, have been published by Hans A. Klagsbrunn in *Industrial and Engineering Chemistry* for July 1945, Vol. 37, p. 608-617.

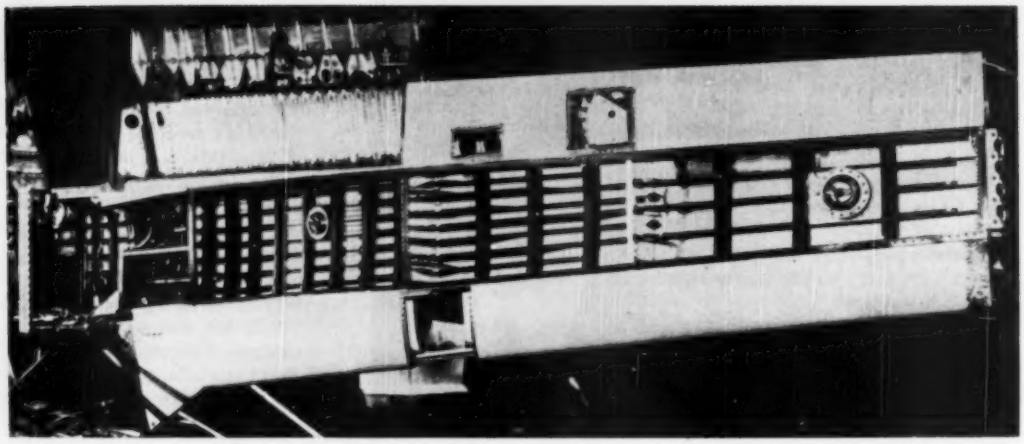


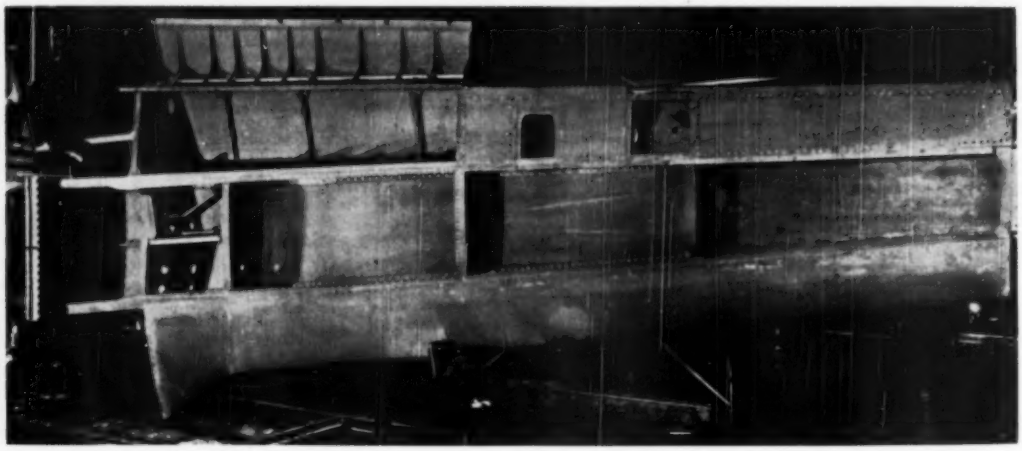
Fig. 4A — Lockheed F-80 Wing Panel (Lower Midsheet Removed) Showing Multitude of Ribs and Rivets in Conventional Construction.

successful results removed from practical planning the theoretical idea found in the literature that magnesium crystals should be deformed slowly! Rather it was proven on full scale that *at the right temperature* magnesium has superior rollability and formability.

Consider the revolution in rolling mill practice that has resulted from this discovery: Present rolling in hand mills begins with 100 to 200-lb. cast slabs, expensive to cast and to scalp. These slabs cool so much in breakdown that they must be reheated several times. The thin sheet is put through the mill one sheet at a time and the thinner the sheet, the harder it is to keep it hot. The final cold rolling process is a long sequence of rolling and annealing.

In contrast to this, the slabs used at Butler weighed 850 lb. and were put through a reversing breakdown mill with enough speed and power so that the metal *gained* heat in the 2 min. required for rolling from 7 in. to 0.4 in. This plate was passed on hot to the tandem mill, coming out a

Fig. 4B — Lockheed F-80 Wing Panel Redesigned With Thick Skin of Magnesium Alloy. Without weight penalty, it provides simplicity of construction, more rugged design, and more usable space; it eliminates 1132 parts and 26,700 fastenings



minute later as 0.050-in. sheet and being coiled at 1200 ft. per min. Since these early tests, made in 1946, alloy slabs weighing about 2000 lb. have been experimentally rolled on large mills.

In present-day production, magnesium is still being rolled, sheet by sheet, on small mills, but a new rolling mill is being designed for erection at Madison, Ill. This will be the first continuous-coil rolling mill for magnesium, and will make wider and cheaper sheet than is now available. Its potential for production milling will be many times the combined capacity of present hand mills and it will insure an adequate supply of magnesium sheet and plate.

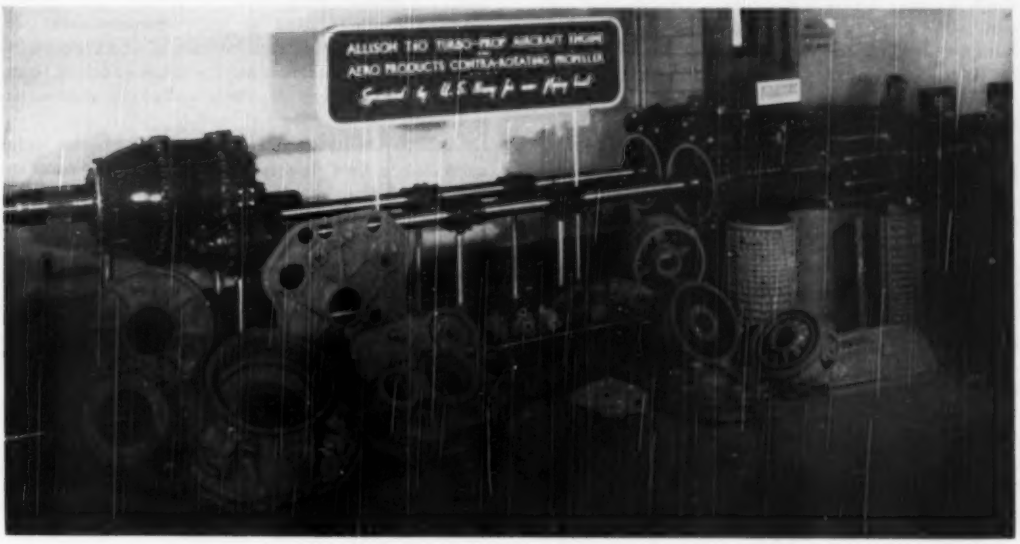


Fig. 5 — Magnesium Sand Castings Used in the Allison T-40 Turboprop Aircraft Engine. This power plant develops 5500 hp. and weighs only 2500 lb.

Extrusions have increased in volume more rapidly than have the other forms of magnesium as a result of the competitive costs attained. Magnesium extrusion equipment is equally as modern as aluminum extrusion equipment; in fact, in some plants both magnesium and aluminum are processed on the same machines. Larger volume, improved die design, alloy compositions with better processing characteristics — all have contributed to the advance. Since the equipment is standard, the industrial capacity of the country can be adjusted relatively easily to the demand.

Sheet Fabrication — Shop practices have been developed in the last 10 years. Whereas no shops had production experience in fabricating magnesium sheet in 1940, many shops now have, including service shops of aircraft companies. Magnesium sheet will take deep draws of 60 to 70% reduction in one draw at the correct temperature. A major problem continues to be the expense of removing the necessary graphite lubricant. It has been amply demonstrated that magnesium can be worked by the common processes of stretch forming, spinning, and impact extrusion. Joints can be made by all standard riveting, welding and adhesive bonding techniques.

Applications and Design

The use of magnesium sheet in aircraft construction can be classified into two types. First is the design in which the necessary gage is already a minimum for stiffness requirements, and, therefore, magnesium can be substituted for aluminum with a small increase in thickness to compensate for its lower modulus; the result is 15 to 20% weight saving. Second is the design utilizing simplified monocoque construction wherein magnesium offers the advantage of increased thickness, and improved stability against compressive buckling without a weight penalty. The East Coast Aeronautics design of the Lockheed F-80 wing is a good illustration of the second (see Fig. 4A and B). Here not only are the number of parts and the labor of assembly vastly reduced, but

usable space for fuel or other purposes is acquired. (A Northrop project just announced contemplates the casting of an entire wing-surface in one piece.) The importance of simplified design in raising production capacity in spite of labor shortage cannot be overemphasized. Magnesium, because it can be used in bulk without too great a weight penalty, offers the opportunity of simplicity and economy of design whether the article be made of plate, extrusions, or castings.

Extrusions are well adapted for labor-saving designs. An illustration is the integrally stiffened sheet stringer panel for aircraft construction. It eliminates rivets and overlapping surfaces, so this item can be lighter and stronger as well. A similar item in the commercial field which has attained a high production and very successful service is highway truck and trailer flooring. Many other examples of complicated assemblies which have been simplified into a single extrusion could be given. Certain parts are designed to be made from short pieces cut from long extrusions.

Important fields of use depend upon the high solution potential of magnesium. Magnesium used as an anode to protect iron and steel from corrosion is a major application. Such anodic protection is applied to pipelines or other underground structures, as well as to water heaters and boilers, or even ships at anchor. Another such use for magnesium is as an anode in batteries using a magnesium bromide electrolyte. This cell has more than twice the capacity of the ordinary Leclanche battery and has other good features for military as well as commercial uses.

Magnesium has long served as an agent to refine lead and nickel. A substantial amount will be absorbed in the production of "ductile cast iron" containing nodular graphite as-cast. Demand will also be increased as the titanium and zirconium markets grow, since magnesium is the reducing agent ordinarily used.

New applications for military purposes have been no less numerous or important, though the commercial or industrial uses for magnesium were almost twice the military uses in the past year (1949). This peacetime growth strengthens the ability of the industry to meet the demands which another national emergency would force upon it.

Metallurgical Developments

Some of the technical developments of the 10-year period have already been mentioned, particularly those which affect production capacity through processing advances. Many others are primarily important because they improve the service characteristics and increase the fields of application and volume demand for magnesium. Many of the wartime research projects continued through 1945-1950, some of them sponsored by governmental agencies.

In Germany, forged magnesium alloys containing *mischmetal* (a mixture of rare earths) were used sparingly in War II for engine parts where high creep strength at elevated temperatures was desirable. Large complicated castings for jet engines (Fig. 5) can be obtained in America in similar compositions. These alloys have a creep strength five to ten times greater than the common alloys, and are comparable to some of the aluminum-base alloys used at high temperatures. It has been established that certain of the rare earth constituents of *mischmetal* are more effective than others, but the most practical technique at present is to add the mixture.

Magnesium alloys containing zirconium were used for a few special aircraft extrusions in War II. Since then Mg-Zr has become a common commercial extrusion alloy with the highest available combination of yield strength and toughness. This optimum combination of properties is also provided by Mg-Zr alloy castings, and considerable work is now underway to evaluate their foundry and service characteristics. Their fatigue characteristics in service have not yet been established.

Both the rare earth and the zirconium-containing alloys greatly improve certain mechanical properties and thus extend the field of usability where their added expense is justified.

Magnesium alloys containing lithium have also received much attention in the last 10 years because of their promise of high mechanical properties. However, as yet it has not been possible to stabilize these alloys at a high-strength level.

A unique metallurgical development which is now in the pilot-plant stage is the extrusion of magnesium alloys formed by mixtures of "atomized" powders averaging about 0.006 in. in diameter. Magnesium-base compositions can be made in this way which cannot be cast. For instance, aluminum is incompatible with zirconium and precipitates zirconium out of the magnesium alloy melt. However, when a powdered magnesium-zirconium alloy is blended with aluminum or magnesium-aluminum alloy powders and extruded in a solid shape, the resultant alloy can be heat treated to precipitate aluminum-zirconium compounds, thus raising the strength by what has been called "interference hardening". In this manner the following properties have been obtained in an extruded ⅞ x ⅛-in. strip: 52,000-psi. tensile strength, 44,000-psi. tensile yield strength, 48,000-psi. compressive yield strength, and 8% elongation. *(Continued on p. 530)*

Once the dominant process in steelmaking, the bessemer has fallen in 50 years to where it makes only 5% of the American tonnage — principally because of quality considerations. It is possible that side-blown converters will reverse this trend.

Developments in Bessemer Steelmaking Since 1940

When the steel industry of the United States faces the need for increased production it is inevitable that the merits of the bessemer process be carefully investigated, and this review is designed to show how the developments of the past 10 years affect the ability of the bessemer process to produce more steel. There has been much activity and some promising accomplishments, but it is a surprising fact that many of the encouraging features are not entirely new. For the most part they can be traced back into the early history of the bessemer process, and they involve a queer mixture of metallurgy, economics and raw materials.

It was the bessemer process that made the steel industry of the last 50 years of the 19th century, and anyone who has worked with the process, and who has seen the spectacular flames coming from a converter at night, cannot fail to have a feeling of regret at the relatively low status to which the process has fallen in the first half of the 20th century. Indeed, many metallurgists have tried to stem the unfavorable trend.

By 1907 the basic openhearth process had pulled up even with the acid bessemer in the United States, and the relative standing of the latter continued to fall until 1946. During the past four years the percentage produced seems to have stabilized at about 5% of the total production. Quite possibly this represents the current demand for which bessemer steel's properties are particularly suitable.

Among the reasons that are given for the rise of the basic openhearth process and the decline of the bessemer are found the following: *(a)* greater ease of control of the openhearth, *(b)* ability to use a wider range of less expensive ores, *(c)* ability to use larger quantities of cheap scrap, and *(d)* superior steel quality. Favoring the bessemer process, on the other hand, are its great speed of operation and the fact that it does not require external fuel.

Bessemer steel has been commonly used for skelp for making lap welded and butt welded pipe; for sheet bar for tin-plate; for screw steel; and for various wire products. Even these uses have been encroached upon. Seamless tubing made of openhearth steel has cut into the market for skelp. Furthermore, the modern method of making tinplate and sheet from hot rolled strip resulted in serious losses in flat products, for the bessemer's extra phosphorus (which helped in rolling on hand-operated hot mills) gave undesirable physical properties to the product of the strip mills.

The problem of steel quality involved in the use of bessemer steel has resolved itself largely

By Harold K. Work
Director of Research Division
College of Engineering
New York University

into the control of nitrogen and phosphorus. Fifty or more years ago, when most of the steel was hot worked, high phosphorus and high nitrogen apparently did not seriously interfere. Today, an increasing quantity of steel is cold worked, and nitrogen and phosphorus cause the steel to be stiffer, less ductile, and more susceptible to work hardening. This is undesirable in many applications. Furthermore the nitrogen content is probably the principal cause of strain aging, with unfavorable implications for many types of steel products.

On the other hand, all of the effects of nitrogen and phosphorus are by no means detrimental. Phosphorus has a beneficial effect on corrosion resistance and machinability. It has also been claimed that nitrogen increases the machinability of steel.

Harold K. Work

Past-President, ⚙

FROM 1936 to 1949, HAROLD WORK was in charge of the research and development division of Jones & Laughlin Steel Corp. One of the important assignments was an intense study of the bessemer process, including all the credits and debits mentioned in this article.

Since these two constituents in blown metal, although present in only small amounts, seem to have such a profound effect on its properties and uses, it seems pertinent to consider briefly what can be done to control their effects. The first and most obvious step would be to reduce them to limits comparable to those of basic openhearth steel. A second possibility, insofar as nitrogen is concerned, consists in combining the nitrogen under proper conditions with some agent such as aluminum.

Economic Factors Involved

The economic problem is more complicated. Various writers have discussed this. Due, however, to the large number of variables involved, it is believed that each student of the subject would arrive at a somewhat differing solution. Nevertheless the idea has been advanced that the prosperity of a given steel company is influenced to a considerable degree by the extent of its bessemer operations — an explanation not without controversial elements.

The principal factors in the steel costs would be *(a)* the cost of the necessary plant, *(b)* the cost of proper raw materials, and *(c)* operating costs. At first glance it might appear that a bessemer plant would cost much less than an openhearth plant of equal capacity. That is true — insofar as the steel works are concerned. However, the converter uses for the most part molten pig iron for the charge; scrap additions ordinarily run under 10%. The openhearth, on the other hand, uses only about 60% iron, the balance of the metallic charge being scrap and ore. This means that a converter plant usually needs about 50% more iron capacity, and to make a fair comparison of plant costs additions should be made for the extra blast furnaces, coke ovens, stockpiles, coal and ore mining facilities, and the like.

Not all of this, of course, is a true gain for the openhearth. Its purchased scrap involves investment, labor, and profit for the scrap dealer. This might well tend to equalize the costs if scrap and iron were the same type of materials, but they are not. Scrap is, in a way, a byproduct and its cost is largely influenced by supply and demand. Iron, which is made from ore, is relatively stable in cost, even though it has been increased by rising labor and transportation costs.

From this brief analysis it is indicated that in periods of high production, such as were experienced during the last 10 years, scrap prices are very likely to rise due to its scarcity. There tends therefore to be economic pressure favoring the bessemer process in periods of prolonged high production. Doubtless this has been a prominent factor in checking the decline since 1946.

Metallurgical Factors

There have also been some technical developments during the last 10 years that tend to help the bessemer process. They are:

1. Greater care in applying converter steel.
2. Dephosphorization.
3. Aluminum killing.
4. Side blowing in *(a)* acid and *(b)* basic.
5. Use of oxygen in the blast.

The war naturally had a pronounced effect on production. It was necessary to produce every possible pound of steel. In that effort considerable care was exercised to use converter steel in every allowable application, and by a concerted effort

on the part of the industry, it was applied advantageously in many places where its use had formerly been frowned upon. This effort has continued after the war but does not seem to have succeeded in greatly improving the position of bessemer steel.

As has been indicated earlier, a high phosphorus content has excluded it from certain products in favor of the softer basic openhearth steel. Two methods have been patented during the last 10 years for reducing the phosphorus. In one the steel is treated in the ladle with a dephosphorizing mixture of lime, roll scale, and fluorspar. The other dephosphorizes bessemer metal in a tilting openhearth: The slag from a low-carbon heat of steel is enriched, when required, with burnt lime and roll scale; the furnace is then charged to capacity with blown metal, and about 30 min. later the heat is tapped. The resulting steel has better ductility and less brittleness under impact than regular bessemer. In addition it is not as stiff and does not react so strongly to cold work. Such dephosphorized bessemer steel, however, does not equal basic openhearth steel in these respects and the difference can, no doubt, be ascribed largely to the fact it still contains the customary nitrogen.

It is therefore interesting to note that another practice designed to control the effect of the nitrogen was also developed in the last decade. It consists of fully killing the steel with aluminum: Blown metal in the vessel is treated with a definite amount of molten iron. The carbon in the iron at these high temperatures serves as a deoxidizer. Since the reaction product is a gas, detrimental inclusions are not formed. Subsequently the blown metal is treated in the ladle with aluminum and other additions. Such steel has a high yield point and high elastic ratio, resembling in some measure the proprietary low-alloy steels. This has recommended it for structural purposes or to withstand high pressures, and it has been extensively used for pipe. Such a superior steel should be much more widely used. There are, however, some obstacles to its production. Few plants are set up so they can handle the extra operations economically and then process the killed ingots properly. Furthermore the method involves an increase in cost. As a consequence it seems to be only a partial answer to the bessemer's problem.

Side-Blown Converters

The fourth important development is the most interesting, the most promising, and the most curious. It consists in using a side-blown converter to secure low-nitrogen steel. This, if coupled with proper provisions for a low-phosphorus metal, seems capable of producing steel of the required high quality.

Perhaps the most curious thing about this development is that it is not new. The first converter of Henry Bessemer was side blown, but he was not able to put it into commercial operation. After further experimentation he developed a bottom-blown vessel which is more or less representative of the one used as a modern tonnage steel producer. However, Bessemer's original side-blown converter was used in Sweden for years; the success there was in part a result of using more suitable iron ores.

For a period of time the side-blown converter found no use in England but in the 1880's Messrs. Griffiths and Clapp revived it. Their converter was much like Bessemer's old converter but it had a tap hole for removing slag and the tuyeres were placed somewhat below the surface of the bath. That process was soon introduced into the United States and presently there were a dozen or more plants producing side-blown steel. A bitter controversy developed concerning quality. On the one hand it was claimed that the steel was soft and ductile and there were some users who were willing to pay a premium for it. On the other hand there were those who strongly opposed the claim of superior properties. The supporters of the process, while they were presumably correct about the superior properties, did not present their case well and apparently lost the argument, for in less than 10 years the process was dropped. Side blowing, however, did not die easily. Laureau, Walrand and Robert, Cambier, Sherk and Rutter, Levoz, Stoughton, Zenzes, Tropenas (to name a few) developed and used various modifications. Nevertheless the side-blown converter eventually lost the struggle with the bottom-blown converter in the steel industry, except for foundry use.

The current revival of interest therefore poses some interesting questions. There must be some reason why such an old principle should suddenly be revived. A brief review may explain this.

During the very early days, after Bessemer had discovered his process, a tremendous amount of energy and ingenuity went into its development. In this period practice was undoubtedly ahead of science. But in recent years science has come to the fore. With a greater amount of technical knowledge it is now possible to reappraise the work of the early steel inventors and to draw new technical values from it. Thus the gap between practice and science has been bridged and steps are currently being taken to do something constructive about the bessemer process in America.

Development of the side-blown vessel has

followed two lines, namely with acid and basic linings, and two different companies participated in the work, at first independently, and then together. Which type will be better for use in the United States presents an interesting problem.

As is well known, the acid converter is largely used in the United States while the basic bessemer is preferred in Europe. This difference is based on the use of pig iron from available ores. With side blowing, however, more heat is developed, and this makes for a possible change in the ore and iron requirements.

The basic lining has the prime advantage that it allows for the control of nitrogen and phosphorus in a single operation. On the other hand if an acid lining is used the steel will normally be high in phosphorus. For some purposes such a steel might be quite satisfactory — in fact, even desirable. However, to get properties like those of basic openhearth steel a dephosphorizing step would then be required. This could be done in the ladle or in an openhearth. The latter would have some advantages to offset the extra operation. Several bessemer heats would be mixed, thereby promoting uniformity, and the resulting larger heats could be so handled as to minimize the inclusions which are frequently present in bessemer steel. Furthermore, better analytical control could be obtained. (The above comparison could be discussed at great length but it is only intended here to present the question, not to attempt to settle it.)

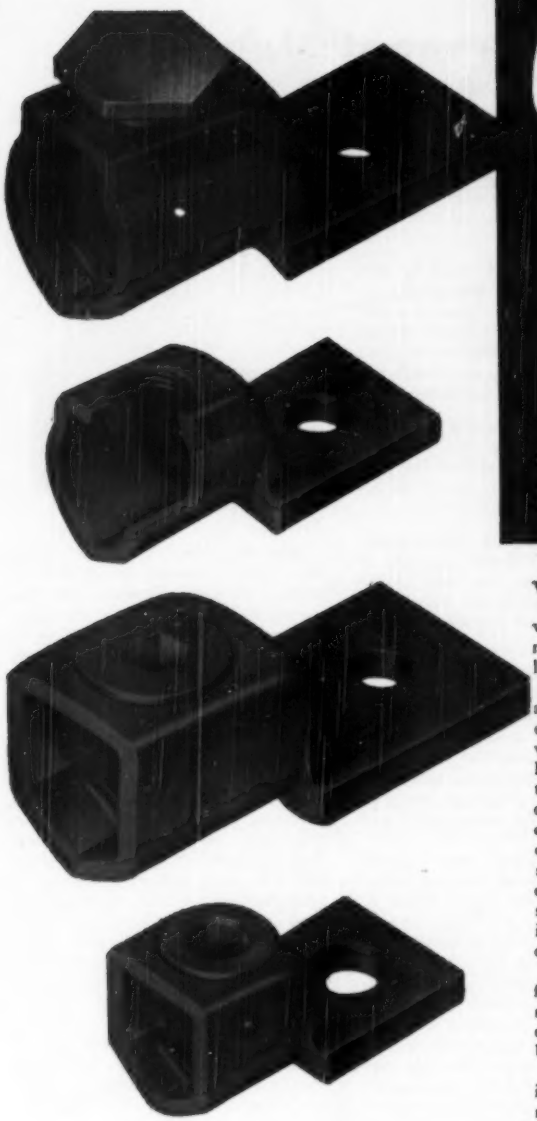
One fact, however, seems clear — namely, that steel of a quality suitable for cold working operations, which now require openhearth steel, can be made in a converter. This has been demonstrated on a fairly large scale and the practice appears metallurgically sound. It still remains to be proved that the requirements of modern plant production can be met in routine commercial operation. While it is true that many side-blown converters were developed and used commercially in the past, these (like the modern foundry converter) were small in size and probably not too efficient in operation. In these small converters the high heat generated was an advantage. With increase in size, however, the tendency toward even higher temperature becomes greater, so temperature control becomes a problem. Excessive temperatures, in turn, mean costly refractories. There are slag problems, too, to be solved. So it will not be simple to put a large side-blown converter into commercial operation, but none of the problems involved seems insurmountable.

Thus far only the metallurgical advantages of side-blown metal have been stressed. But there may also be economic advantages. Side blowing generates considerably more heat than bottom blowing, so the side-blown converter can undoubtedly be used to melt more scrap. Furthermore, if the blast were enriched with oxygen, the amount of scrap might be increased considerably. If this were done successfully in the mills there would be available a steelmaking process with *(a)* low plant cost, *(b)* great speed and economy of operation, *(c)* great adaptability and *(d)* capable of producing steel of very high quality.

A development just mentioned that is attracting attention in the United States is the enrichment of the blast with oxygen. This is another old idea which has been revived on the heels of cheap methods for producing tonnage oxygen. It has certain advantages such as shortening the blowing time, decrease in nitrogen pickup during blowing, and increased capacity for melting scrap. It is still too early to say whether or not this practice will find a place in the mills.

More or less independent of these studies and small-scale operations in America, some of the underlying principles have been used in Europe. The shallow bath to reduce nitrogen, oxygen enriched blasts, and even side blowing have been used — the first two in production and the last, apparently, only experimentally.

Future Possibilities — No discussion of this type would be complete without some brief comments as to the future possibilities of the bessemer process. It is apparent that the bessemer process in the United States is currently in a bad way. This situation could become even worse. Or the process might hang onto its present low level of production. However, from the above considerations it would appear that side blowing has at least a possibility of reversing the current unfavorable trend, and causing the bessemer process to resume a more important place in the production of steel in America.



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Personal Mention

John McConnell

In the deliberations of the ⊖ committee which had in 1948 the delicate task of selecting the great names in alloy steel, there was instant agreement about the beginnings of commercial activity in America: United Steel Co. of Canton was the place; Henry Ford's demand for chromium-vanadium steel was the occasion; **John McConnell** and Fred Griffiths were the men who made it. It is well to recall those facts, for John McConnell, the legendary steelmaster, is now retired these 23 years, and only a name to the present generation. His citation was "for pioneering the production of alloy steels in the open-hearth furnace".

He was born Sept. 28, 1861, in the northern part of Ireland. Ten years later his family moved to Scotland, and not long thereafter John went to work. The acid openhearth process, commercialized in England in 1868, was just being adopted by the Scottish companies, and John McConnell grew up with the process, being a melter at the age of 26 when he emigrated to America.

Andrew Carnegie, three years before, had bought the Homestead plant and decided to build four large furnaces — all of 50 tons — for making steel by the new openhearth process, despite its unfavorable record in other American plants. There was a need for men who knew the process, and McConnell became a melter at Homestead, the very next year helping in the conversion to basic linings and working out the new techniques of operation.

Like many of his profession, he traveled about a bit, becoming melt-shop superintendent successively at South Chicago, J. & L.'s South Works at Pittsburgh, Lukens at Coatesville, and finally at Bethlehem, where he became acquainted with the early alloy steels used for armor, guns and projectiles.

By then, United Steel Co. of Canton had started making chromium-vanadium for Ford's Model T. Despite a year's preliminary experimentation, commercial production was having its troubles, so in 1908 Harry R. Jones, the president, asked McConnell to take over as plant superintendent. His success paralleled the rising importance of the automobile; by 1915 United was America's largest producer of alloy and its ten openhearths and well-developed finishing departments were a prime source of ordnance steels.

After the war, John McConnell became vice-president of Interstate Iron & Steel of Chicago (now a part of Republic Steel Corp.) and he and Andy Forrest, openhearth superintendent, successfully put that firm into the alloy steel business. However, by 1922 he was back with United in Canton as vice-president in charge of alloy steel production, where he remained until retirement in 1927, at the age of 66.

S. T. Jazwinski ⊖, formerly a consulting engineer and chief metallurgist and vice-president of Barium Steel Corp., was recently appointed senior staff engineer of the Ford Motor Co., Detroit.

R. F. R. Graser ⊖, formerly with ballistic research laboratories at White Sands Proving Grounds, is now associated with the Ordnance Guided Missile Center, Redstone Arsenal, Huntsville, Ala., as a metallurgist in the material testing laboratory.

R. L. Keller ⊖, formerly with the Carborundum Co., is now with the technical service division of the metallurgical department, Vanadium-Alloys Steel Co., Latrobe, Pa.

John C. Coonley ⊖, who was previously assistant works manager of Heald Machine Co., has been named assistant manager of the Valve Div., American Car and Foundry, Detroit.

T. Keith Glennan

The most recent appointment to the Atomic Energy Commission is that of **T. Keith Glennan**, who was named to the position by President Truman on Aug. 11 with the Senate's confirmation coming 11 days later. Three years ago Dr. Glennan became president of Case Institute of Technology, Cleveland, after considerable executive experience in the movie industry, as administrator and later director of the United States Navy Underwater Sound Laboratory, and at Ansco Div. of General Aniline & Film Corp. He is a graduate of Sheffield Scientific School of Yale University and holds honorary degrees of Doctor of Science from Clarkson College of Technology and Oberlin College. He also holds a Medal of Merit for his wartime services in the New London, Conn., Underwater Sound Laboratory.

James A. Clark ⊖, formerly with Vanadium-Alloys Steel Co., has joined Pratt & Letchworth Co., Buffalo, N. Y., as assistant superintendent of melting.

Spencer R. Baen ⊖, who received his Ph.D. from California Institute of Technology in June, is now a test officer at the Army Field Forces Board No. 2, Ft. Knox, Ky.

Quentin C. Soprano ⊖, who received his M.S. from Pennsylvania State College in June under the U.S. Army career plan, has returned to military service with the Ordnance Corps, and is now stationed at the Rock Island (Ill.) Arsenal Laboratory.

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Personals

Midvale Co., Philadelphia, announces the appointment of **Howard C. Myers, Jr.**, ⊖ as production manager and **Calvin McKee** ⊖ as assistant engineer of tests.

D. Zimmerman ⊖ has recently been named a junior industrial engineer with the Owens-Illinois Glass Co., Alton, Ill.

Lindberg Engineering Co., Chicago, announces the following changes: **Carl F. Burling** ⊖ has been transferred from their Buffalo office to the Chicago office to be district manager of the northern Illinois sales territory, **R. K. Rawlins** ⊖ has been assigned to handle the central Illinois sales area, and **Philip J. Duffy** ⊖ will take over the Calumet district.

Louis M. Teich ⊖, who has been a salesman for Latrobe Electric Steel Co. in the Philadelphia district for three years, has been appointed branch manager of the Philadelphia office and warehouse.

I. R. Leheny ⊖, formerly manager of the San Francisco district of Allegheny Ludlum Steel Corp. and a past-chairman of the Golden Gate Chapter of the American Society for Metals, has been appointed assistant manager of cutting tool sales for Allegheny Ludlum. **Guy M. Winton** ⊖ has been appointed manager of the San Francisco district.

Carnegie-Illinois Steel Corp. announces that **Dennis J. Carney** ⊖ has been promoted from physicist to general supervisor of metals research at its South works.

R. B. Hoffman ⊖, who graduated from Lafayette College in June 1950, has accepted a position as metallurgist with Treadwell Engineering Co., Easton, Pa.

D. P. Cassidy ⊖ has recently been appointed metallurgical engineer and **James Taylor** ⊖, consulting metallurgist of American Locomotive Co., Schenectady.

William L. Allman ⊖, a lubrication engineer with the industrial department, Socony-Vacuum Oil Co., has been transferred from the Albany, N. Y., area to Connecticut.

Franklin Page, Jr., ⊖, a recent graduate from California Institute of Technology, is now connected with Sierra Engineering Co., Sierra Madre, Calif.

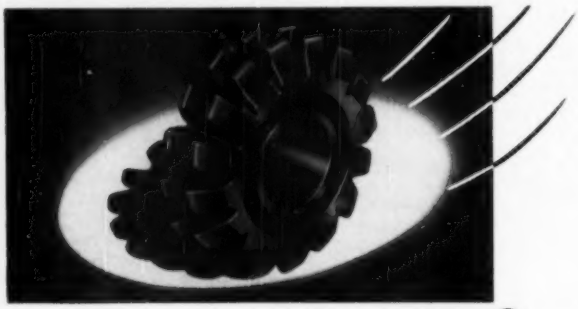
Paul C. Sandmeyer ⊖ has been appointed vice-president of Stainless Steel Sales Corp., Philadelphia. He has been with the company since 1948 and prior to this was with Pittsburgh Steel Co., Jessop Steel Co. and Carnegie-Illinois Steel Corp.

L. L. Marsh, Jr., ⊖, a recent graduate in metallurgy from Case Institute of Technology, has been appointed to the staff of Battelle Memorial Institute, Columbus, Ohio, where he will be engaged in research on engineering materials.

William W. Wright, Jr., ⊖, a 1950 graduate of Grove City College, is now employed as plant metallurgist now employed as plant metallurgist, Newcomer Products, Inc., Latrobe, Pa.

Edwin S. Bartlett ⊖, a recent graduate of Michigan College of Mining and Technology, has accepted a position as metallurgical engineer with Hoskins Mfg. Co., Detroit.

Percy A. Haythorne ⊖, associated with Lockheed Aircraft Corp. for the past nine years as research engineer in charge of metallurgical research, has recently resigned his position to devote his time to his consulting practice exclusively.



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Personals

Roman Smoluchowski, professor of metallurgical engineering at Carnegie Institute of Technology, has been appointed as a consultant to the chairman of the Research and Development Board, Washington, D.C. He will consult on matters pertaining to the physics of solids while retaining his position at Carnegie Tech.

Howard H. Wilder has been appointed manager of the iron foundry division of the Vanadium Corp. of America, with headquarters in Detroit. Mr. Wilder was formerly chief metallurgist of the Eaton Mfg. Co.'s foundry division at Vassar, Mich.

W. H. Schmalhorst, a recent graduate from the University of Michigan, has joined the staff of United Engineering & Foundry Co., Vandergrift, Pa., where he will be engaged in inspection and quality control.

L. H. Brandt, formerly manager of technical service for Pennsylvania Salt Mfg. Co., has been named product supervisor in its Philadelphia office.

Carnegie-Illinois Steel Corp. announces that **Ralph W. Dickson**, who has been with the company since 1927, has been made division superintendent of the central mills.

Roy B. McCauley, Jr., formerly a member of the department of metallurgical engineering of the Illinois Institute of Technology, is now on the staff of the welding engineering department at Ohio State University.

Charles H. Parcells, who received his master's degree in June at Illinois Institute of Technology, has been appointed an instructor in metallurgical engineering at the institute.

Edward Valves, Inc., East Chicago, Ind., announces that **Laurence H. Carr** has been named director of engineering and research. He has been on the Edward technical staff since 1936 and he was chief metallurgist previous to his new appointment.

Vincent J. Coppola, formerly instructor of metallurgy at Iowa State College, is now with the Kearney and Trecker Corp., Milwaukee.

Bani R. Banerjee, formerly research engineer, Standard Oil Co., Chicago, has joined the faculty of the University of Calcutta, India.

Verne H. Schnee, director of the University of Oklahoma Research Institute, has been appointed vice-president in charge of development of the university. Mr. Schnee joined Oklahoma in 1949 after 15 years at Battelle Memorial Institute, where he was assistant to the director.

Benjamin Sampson, formerly district sales manager of the Stewart Div. of the Sunbeam Corp. and recently manager of the Industrial Furnace and Oven Div. of the Claud S. Gordon Co., has been appointed general sales manager of the K. H. Huppert Co., Chicago.

Robert A. Fitch has been promoted by Gulf Oil Corp. and Gulf Refining Co. from lubrication engineer in the New York division office to chief fuels and lubricants engineer in the metallurgical section of the industrial products engineering department.

H. B. Myers, formerly technical director of Roll Manufacturers Institute, is now metallurgical engineer of the S. H. Bell Co., Pittsburgh, where he is engaged in selling ferroalloys and pig iron produced by the Tennessee Products and Chemical Corp.

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Personals

Harry L. Jenter has been named chief engineer by American Steel & Wire Co. His former position of general superintendent of the Cuyahoga works, Cleveland, will be filled by **Nelson W. Dempsey** who has been transferred by the company from the Waukegan, Ill., plant, where he also held the position of general superintendent.

Jessop Steel Co., Washington, Pa., announces the appointment of **John R. Harbaugh** as assistant general manager of sales. He has been associated with the company for the past ten years doing special assignment work in metallurgical sales. **Homer A. Mawhinney** has also been appointed district manager of the southern territory with offices in Birmingham, Ala. He was formerly district manager in Chicago.

Edward E. Murray, formerly chemist for Ohio Ferro Alloys Corp., Tacoma, Wash., is now a radiographer at Boeing Aircraft Co., Seattle, Wash.

Guy V. Bennett, who graduated from South Dakota School of Mines and Technology in June 1950, has joined the staff of the Argonne National Laboratory, Chicago, as a junior metallurgist.

Irving J. Donahue, formerly superintendent of Presmet Corp., Worcester, Mass., is doing consulting work on the West Coast and at present is installing a powder metallurgy division for a large manufacturer in that area.

John Haydock, formerly vice-president and editor of *Design News*, has recently been made editor and assistant publisher of *Metal Working Magazine*.

After graduation from Columbia University in June, **Philip E. Lapat** has accepted a position as metallurgist with American Light Alloys, Inc., West Paterson, N. J.

Austin E. Dwight, who received his M.S. from the University of Michigan in 1949, is at present a metallurgical engineer with the naval reactor division, Argonne National Laboratory, Chicago.

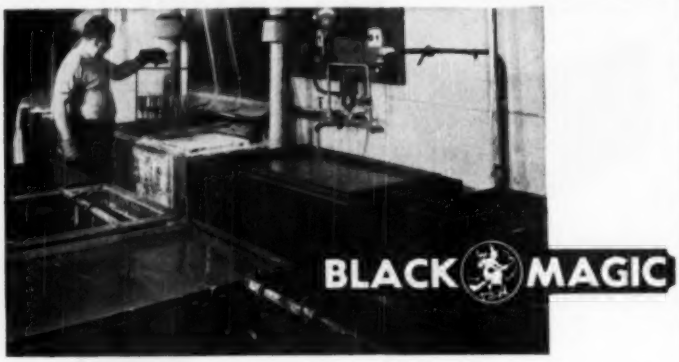
Robert C. Anderson has been appointed metallurgical engineer at the N.E.P.A. Div., Fairchild Engine and Airplane Corp., Oak Ridge, Tenn.

Rudolph F. Spacek has accepted a position as metallurgical engineer in the research division of the American Can Co. in Maywood, Ill.

Following graduation from the Missouri School of Mines and Metallurgy, **Ray A. Warfield, Jr.,** has accepted the position of junior metallurgist at Colorado Fuel and Iron Corp., Pueblo, Colo.

A metallurgical engineering graduate of the University of Washington in June 1950, **Birney S. Covell, Jr.,** is now employed as a metallugist at the Northwest Electro-Development Laboratories of the U. S. Bureau of Mines in Albany, Ore.

Zay Jeffries, past-president of the American Society for Metals and until recently vice-president of General Electric Co., **Clyde E Williams**, director of Battelle Memorial Institute, **Bayard D. Kunkle**, a member of the board of directors of General Motors Corp., and **Roger Adams**, president of the American Association for the Advancement of Science, have been responsible for the formation of Growth Companies, Inc., Philadelphia. The new organization will invest its funds in the common stock of companies believed by the directors to possess more than ordinary possibilities for growth.



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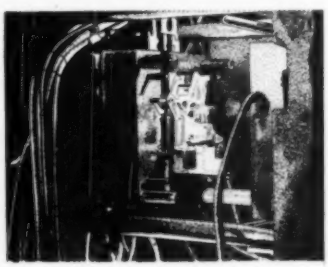
(Mr. Hanawalt's article starts on p. 512)

It has also been demonstrated that the stress corrosion sensitivity of the magnesium-aluminum type alloys can be inhibited by the extrusion of mixtures of the Mg-Al alloy powder with Mg-Mn alloy powder. This is probably due to the fact that the Mg-Mn constituent is anodic to the other. Other noteworthy advantages of this new powder-extrusion process are grain size control, and elimination of billet casting and scalping.

Besides improved surface treatments of chemical nature for cleaning the metal or for a basis of a protective coating, two specific developments in the surface finishing field will serve to extend the utility of magnesium. First of these is electroplating, which is successful by standard techniques and with the usual metals, following an initial zinc coating easily put on the magnesium by immersion in a solution containing tetrasodium pyrophosphate and zinc sulphate. Surprisingly enough, a nickel-chromium plate is quite protective even in salt exposure where its cathodic potential might have been expected to cause corrosion. Other plated coatings are useful for their hardness and wear resistance. The other finishing development of outstanding importance is a new paint primer which, applied either to bare metal or to chemically treated magnesium, has superior adhesion and protective value to any previously known.

Summary

In conclusion it might be said that the magnesium industry itself today is in a very different situation in almost all ways than it was in 1939. American consumption is on more than ten times the 1939 level. The Government-built wartime ingot plants are in standby condition. Wrought magnesium fabrication has been highly developed, and shop skills are widespread. Many new uses, both military and commercial, have been introduced into production. Much more information on properties is now available, as well as better design data. The possibility, through the use of magnesium, to simplify the design and fabrication of an article has been demonstrated — important because of the consequent reduction of man-hours and increase of plant productive capacity. In any future national emergency, the demand on the magnesium industry will be prompter and greater than in War II, but the ability to meet that demand rapidly has been vastly increased.



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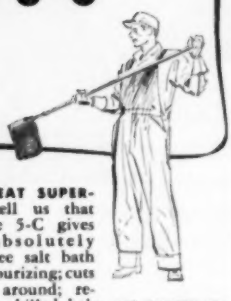

Automotive door parts. Carburized up to 40 min. in PK-5C at 1500° F. oil-quenched. Case depths .008" to .012". All parts cadmium plated after casing in free-cleaning PK-5C.

Screw nut SAE 1118 oil quenched from PK-5C at 1550° F. 2 hours .020" case depth. Jack screw SAE 1027. In PK-5C for 20 min. roller quenched in oil. Pieces washed and plated.

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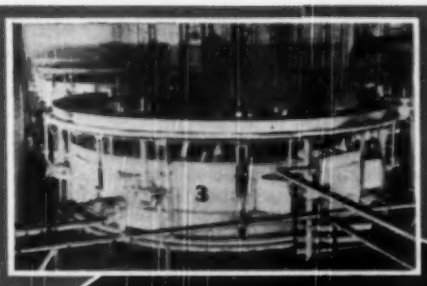

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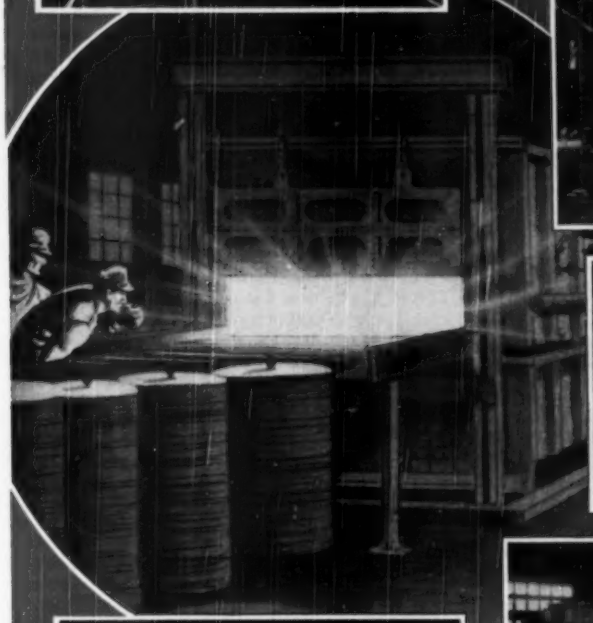

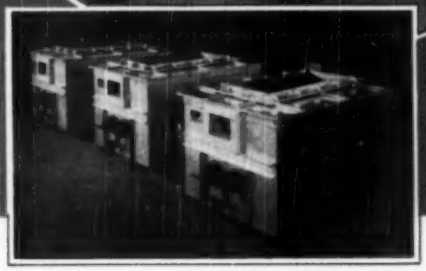

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Direct Iron

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE has issued a report (B.I.O.S. Overall Report No. 15) on "The Ferrous Metal Industry in Germany, 1939-1949", summarizing a large number of reports made by British and American investigating teams.* Its formulation was by George Patchin, formerly principal of the Sir John Cass Technical Institute, and Ernest Brewin, intelligence officer of the British Iron and Steel Federation. The early portion contains some notes on two processes for direct reduction of iron ore to metal, without melting.

Krupp-Renn Process metal was intended for use in lieu of scrap or cold pig iron as part of the charge for openhearth or electric furnaces. When operating on low-grade ores, the metal produced was too high in sulphur and phosphorus and the metal product (called "luppen") had to be smelted in the blast furnace and the process became virtually another method of concentration.

The principle of the process is the reduction of iron oxide by solid carbon, by progressively heating a mixture of fine ore and coke in a rotary kiln fired by pulverized coal. The air supply had to be controlled (to maintain CO and oxygen as low as possible and CO_2 as high as possible throughout the length of the kiln) in order to insure a reducing atmosphere. The reduced metal is prevented from being re-oxidized in the hottest zone by the coating of slag which theoretically forms around the particles of iron.

Kilns were 230 ft. long and nearly 14 ft. diameter in the shell, but the brick lining reduced this diameter to 12 ft. The slope of the kiln was 2% and its speed 1 rotation per min. The burden averaged approximately 68% ore (70% below 5 mm. in size, 30% 5 to 10 mm.), 16% coke (80% below 5 mm. in size, 20% 5 to 10 mm.), 9% returned fines from the concentrators, and 7% flue dust. The lining of the kiln gave trouble toward the discharge end, where a temperature of 2250° F. has to be attained to fuse the metallic particles together into small pellets. This problem was solved by the use of Silesian ganister.

Ring formation, which took place principally between 1100 and 1800° F., was the principal trouble—a trouble avoided in Schmidt kilns by fitting them with a scraper long enough to reach the end of the ring-forming zone, and using them almost continually.

The product of the kiln consisted of a pasty mass of *luppen* embedded in slag. It was quenched with water, and slag separated from metal by ball mills, shaking screens and electromagnetic separators.†

The analysis of *luppen* was reported as 92 to 95% Fe, 0.9 to 1.3% P, 0.3 to 0.9% S (according to fuel used), 0.5 to 1.0% C, and the remainder slag.

Edwin Sponge Iron Process is based on the gaseous reduction of high-grade ore at 1825° F. by a countercurrent *(Cont. on p. 534)*

*This document (and the others listed in the footnotes) is for sale by His Majesty's Stationery Office, London, England; 4s. 10d.

†Further details are given in B.I.O.S. Report XXXII-119, "German Iron and Steel Industry, Ruhr and Salzgilter Areas" (12s. 10d.); B.I.O.S. Final Report 592, "Iron Ore Preparation in Germany" (2s. 8d.); and F.I.A.T. Report 799, "Krupp-Renn and Other Processes for Utilizing Low-Grade Iron Ores" (2s. 8d.).

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Direct Iron

(Starts on p. 532) stream of gas containing approximately 60% CO and 40% H_2, preheated to 1825° F.

The furnace is built up of successive layers of so-called muffles or containers laid on top of one another and arranged to form separate columns, the first being a preheater, the second a reduction column, and the third a cooling column. A container or muffle with a fresh cold charge is inserted at the top of the first column, moves by progressive steps — down, up, and down the three aforementioned columns — and eventually leaves the bottom of the third tier at a temperature of 125° F. The sidewise shift from the top of the reduction tower to the top of the cooling tower has to take place in a gastight hood.

Essential features of the process are the regeneration of gas from the top of the reducing tower and also the employment of the Schönherr arc furnace (used in the nitrogen industry) for preheating the reduction gases.

Briquettes of high grade Swedish ore fines were used as charge in this process as installed at Bochum. A typical analysis of sponge iron showed total iron 93%, oxygen 2.2%, silica 3.67%, carbon 1%, sulphur 0.02% and phosphorus 0.01%.

Total efficiency of the plant calculated on the chemical energy absorbed by reduction of sponge, as compared with the gross energy input, was 50%. (See also F.I.A.T. Report 755, "Highlights of German Iron and Steel Production Technology"; 12s. 3d.)

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Infiltrated Alloys of Refractory Metals*

ALTHOUGH refractory metals and many refractory metal carbides possess high strength at elevated temperatures when used in a non-oxidizing atmosphere, they cannot be used under oxidizing conditions because of the rapid formation of volatile oxides. These metals and metal carbides are usually produced by the powder metallurgy technique. When compacted and sintered under suitable conditions, they form porous skeletons.

The method of infiltrating a skeleton of a higher melting point metal with a liquid metal or alloy of a lower melting point (see *Metal Progress*, Jan. 1950, p. 64 and 106) can be applied to these skeletons using corrosion resistant nickel or cobalt alloys of the Nichrome, Hastelloy, Stellite or Vitallium type as infiltrants. One may then expect to obtain a material that will withstand deformation and creep at high temperatures in the manner of the refractory metals and metal carbides and at the same time retain a high proportion of the resistance to oxidation and corrosion of the infiltrant alloy. The report presents some preliminary experiments on infiltrated tungsten carbide, tungsten-titanium double carbides, titanium carbide and chromium boride as skeletons and a somewhat more detailed study of (Cont. on p. 536)

*Abstracted by F. V. Lenel from A. F. Technical Report 5892, A.T.I. No. 57154, U.S. Air Force, Air Materiel Command, by J. M. Krol and C. G. Goetzel.

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Infiltrated Alloys

(Starts on p. 534) the properties of infiltrated molybdenum, tungsten, and the alloys of molybdenum and tungsten with each other and with chromium.

Both cold and hot pressing were employed to produce the skeleton bodies. The majority of the skeletons were impregnated by heating the skeleton in contact with the impregnant to a temperature above the melting range of the impregnant and letting the impregnant fill the pores of the skeleton by capillary force. External force such as vacuum or pressure was sometimes employed.

Although tungsten carbide could be infiltrated readily, the infiltrated material was attacked rapidly by still air at 1800° F. and the surface regions were decomposed. Impregnated titanium carbide skeletons, on the other hand, gave sound structures, which had appreciable stability against attack by oxygen at 1800° F. but were brittle at room temperature. Sound and uniform structures of infiltrated chromium boride could not be produced by the technique used.

The specimens were evaluated by measuring the increase in weight after holding at 1800° F. and occasionally higher temperatures using Nichrome 5 as a standard, and by transverse rupture tests at room temperature and at 1800° F. on 3 x ⅜ x ¼-in. flat specimens. None of the impregnated molybdenum and molybdenum alloy specimens was satisfactory, because of the poor stability of these materials in air at 1800° F. Somewhat improved oxidation resistance was encountered in tungsten skeletons impregnated with Nichrome 5 and Hastelloy C, although the rate of attack was still several times as high as for Nichrome 5. When alloys of tungsten with 25% chromium were used as the skeleton and Nichrome 5 as an infiltrant, the oxidation resistance at temperatures up to 2200° F. became equivalent to that of Nichrome 5. It was difficult to obtain sound impregnated compound materials with all of the refractory metals because of the rapid reaction between skeleton and impregnant at the impregnation temperature. (Treatments such as chromizing the skeleton before impregnation were of little help in overcoming this difficulty.) For this reason, the transverse strength of the samples varied over a wide range, depending on their soundness, and this should be considered in evaluating the appended maximum values obtained for transverse strength:

Impregnated Alloys	Transverse Strength 1800° F.	70° F.
100% W	80,000 psi.	200,000 psi.
85 W, 15 Cr	104,000	216,000
75 W, 25 Cr	77,000	133,000

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Semicontinuous Casting of Bronze Rod*

THE POSSIBILITIES of even semicontinuous casting of phosphor bronze (composition, tin 10%, phosphorus 0.6 to 0.8%) in 1 and 2-in. diameter rods, *(Cont. on p. 538)*

*"Production in Simple Semicontinuous Casting Machine", by W. T. Pell-Walpole and V. Kondic, Tin Research Institute, Inc., 492 West 6th Avenue, Columbus, Ohio.

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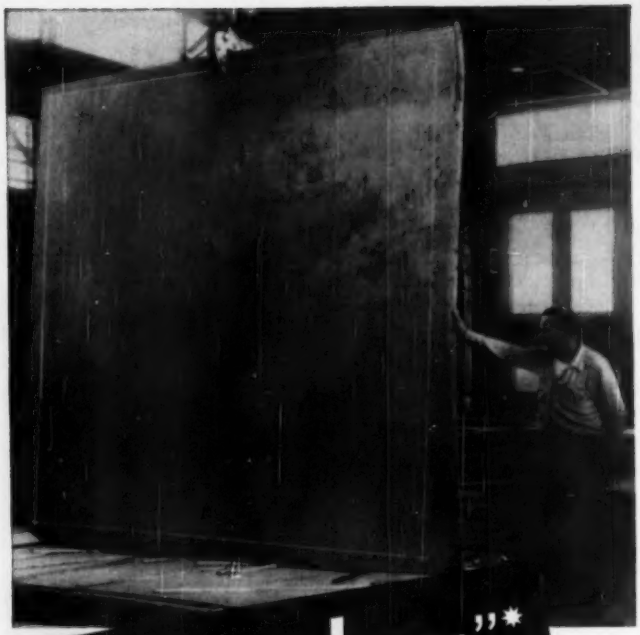

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Bronze Rod

(Starts on p. 536) 3 ft. long, is of interest especially to those companies whose sales field does not warrant the huge expense of such layouts as Scovill's (see *Metal Progress*, January 1950, p. 51).

The authors have devised a very practical machine which gives bars of uniform density: 8.85 — which, if we take 8.92 as maximum density for this alloy, is extremely satisfactory. The pouring temperature of 2100 to 2200° F. and the rate of pouring through an aperture of $\frac{5}{64}$ and $\frac{7}{64}$ in. for 1 and 2-in. rods, respectively, are critical and must be closely maintained.

The dies (open-end molds) are made of copper with 0.5% chromium. A dressing of equal parts tallow and graphite was used at first; later a thin coating of resin-base aluminum paint. Graphite was tried for dies but it was not found suitable. Water cooling by a ring jet with a triple layer of multiple holes was used. The upper series of water jets sprays on the die and the lower two on the extruding rod. City water pressure is used.

Photos of typical macrostructure are given. Sketches of the machine, which is hand operated, form part of the text. H. J. R.

Free-Machining Steel*

FREE-MACHINING steels usually obtain their superior machinability through high sulphur or phosphorus contents. The great majority are turned into parts, such as bolts, in which the major stresses are parallel to the direction of rolling. In such parts the mechanical effects of the sulphur and phosphorus are expected to be at a minimum.

Only limited information has been published concerning the ability of free-machining steels to deform and absorb energy prior to fracture. The present experimental work was undertaken in two

(Continued on p. 540)

*Abstracted from "Free-Machining Steels — A Report on Ductility and Impact Resistance", by W. Lee Williams, *Journal*, American Society of Naval Engineers, Vol. 61, 1949, p. 543-554.

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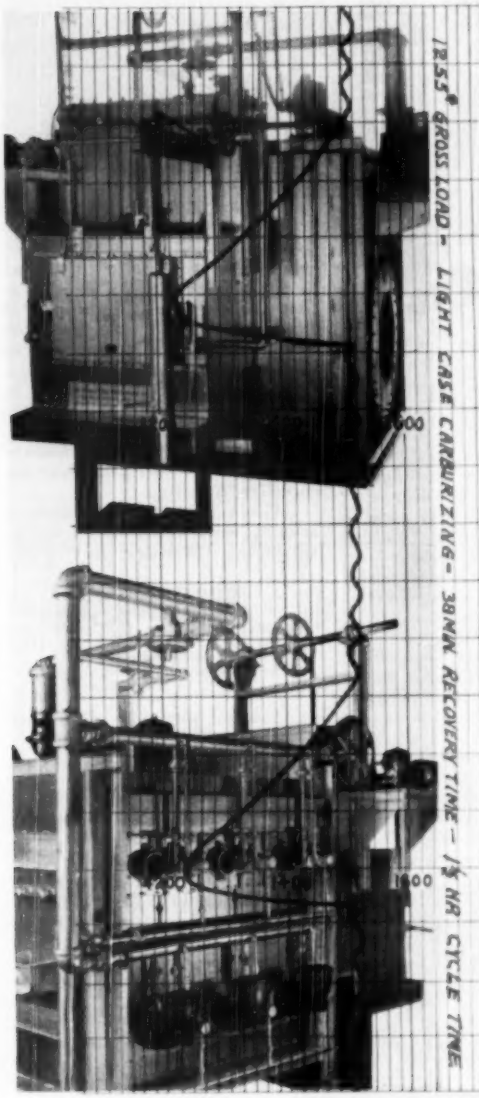

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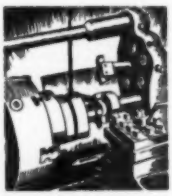
Free-Machining Steel

(Starts on p. 538)

phases: The first pertained to commercial free-machining steels, treated as a general class, to determine whether sulphur and phosphorus had a predominant influence on ductility and impact resistance. The second phase consisted of a study of three series of steels in which all known variables were held constant while the sulphur contents were changed.

In the first phase of the investigation each of 25 commercial steels was tested in three conditions — as-rolled, annealed, and quenched and tempered at 1000° F. This tempering temperature was selected so that all the steels, regardless of hardenability, could be machined readily after treatment. The quenching and annealing temperatures were selected according to carbon content, which was from 0.10 to 0.48%. All conclusions are based on tests in which specimens were cut and tested parallel to the direction of rolling.

Within the range of hardness usually encountered, there is no significant difference in tensile



strength, for equal hardness, between free-machining and plain carbon steels.

In general, free-machining steels as a class have slightly lower ductility than corresponding non-free-machining varieties of equal hardness for the quenched and tempered condition, as shown in the accompanying graph. Similar diagrams for the annealed and hot rolled steels presented too much scatter of test points to allow representative curves to be drawn. However, the trend was definitely toward lower ductility in the free-machining varieties. In contrast, the diagrams for the cold finished steels showed no significant difference between the two general classes of materials.

(Continued on p. 542)

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Kentanium compositions are composed mainly of titanium carbide with other refractory carbides, and an auxiliary metal. They provide higher strength and resistance to oxidation than cast alloys at 1800° F. and above; and greater thermal shock resistance than ceramics.

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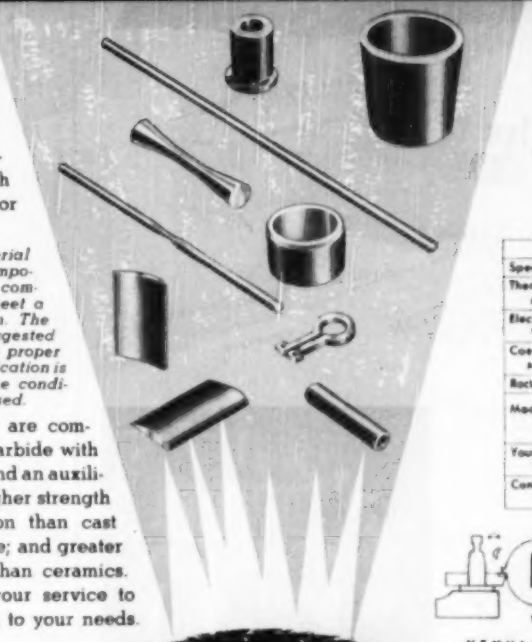

Typical useful applications of Kentanium include: Elements of aircraft propulsion units; hot spinning tools; bushing and shear for hot rod; thermocouple protection tubes; hot extrusion dies; furnace parts; balls for hot Brinell testing; anvils for spot welding; and many others.

Characteristics

Property		Range
Specific Gravity GMS/cc		5.4 – 6.0
Thermal Conductivity cal/sec/°C./cm		.075 – .085
Electrical Conductivity % of Copper Standard		1.9 – 5.0
Coeff. of Thermal Expansion x10-6/°F. up to 1200°F.		4.5 – 5.0
Rockwell A Hardness		87.5 – 93.0
Modulus of Rupture 1000 psi	Room Temp.	112 – 190
	1800°F.	Approx. 100
Young's Mod. of Elasticity 1,000,000 psi		51.2 – 57.3
Compressive Strength 1000 psi		Approx. 550

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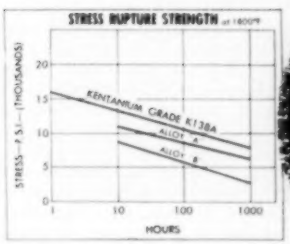
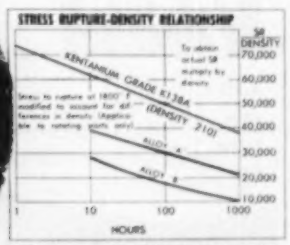


KENTANIUM shows marked superiority in stress rupture characteristics over two commonly-used blade alloys.



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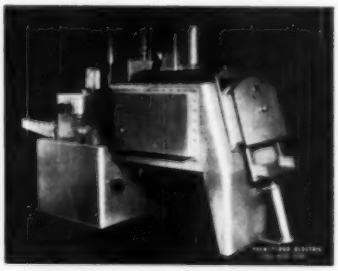

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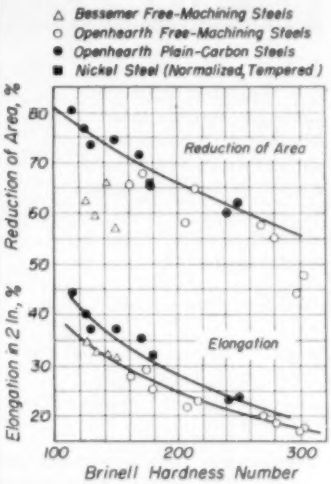
Booth No. 715 at the Metal Show

Free-Machining Steel

(Starts on p. 538)

For any particular steel, including the plain and sulphurized varieties, the quenched and tempered condition results in the lowest transition impact temperature, as determined by the Charpy keyhole test. Usually the annealed condition gives the highest transition.

The basic openhearth grades of free-machining steels compare favorably with the basic openhearth plain carbon steels with regard to

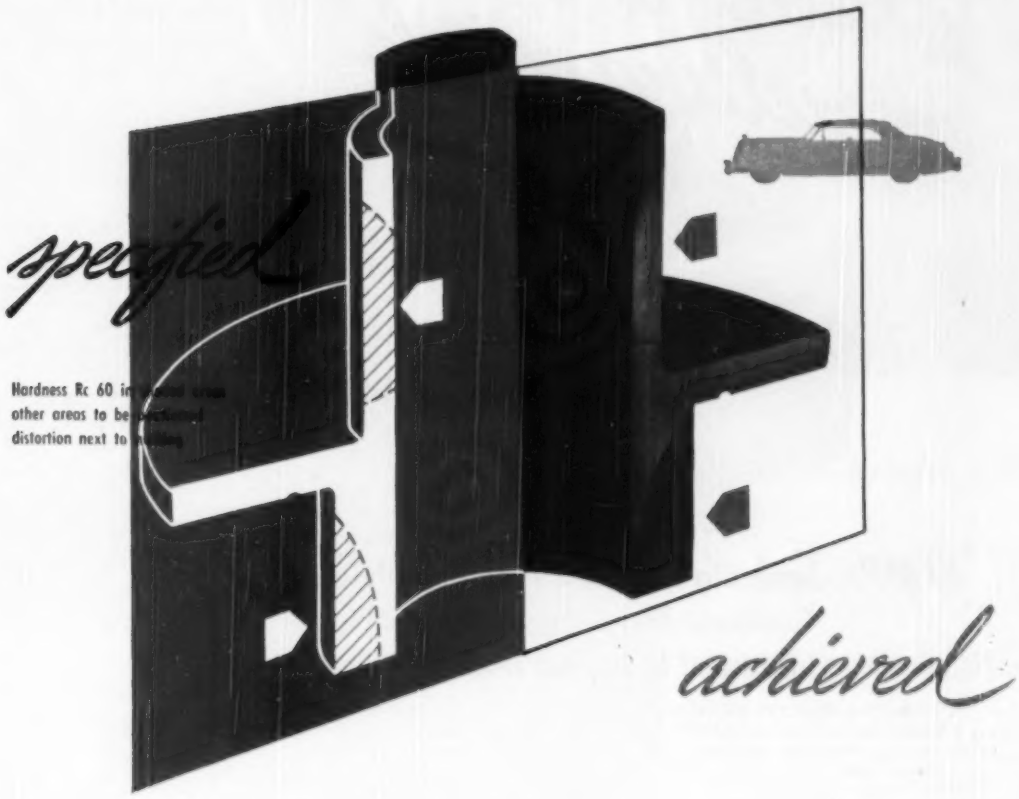


Relation of Brinell Hardness Number to Elongation and Reduction of Area for Quenched and Tempered Steels

critical impact temperature. The acid bessemer steels are inferior to the openhearth steels in this test. The addition of 3.4% nickel to a 0.30% carbon steel lowers the embrittling temperature very effectively.

Steels having controlled sulphur content were available from a previous investigation. There were three groups of eight steels each. One group had 0.20% carbon with sulphur varying from 0.033 to 0.136%. Similar groups were available with 0.37 and 0.78% carbon. No correlation could be observed between sulphur content and critical impact temperature. The effect of sulphur in this respect is insignificant compared with the other variables known to influence impact behavior.

another part for a torque converter transmission



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Gas Turbine Alloys

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for article starting on p. 503

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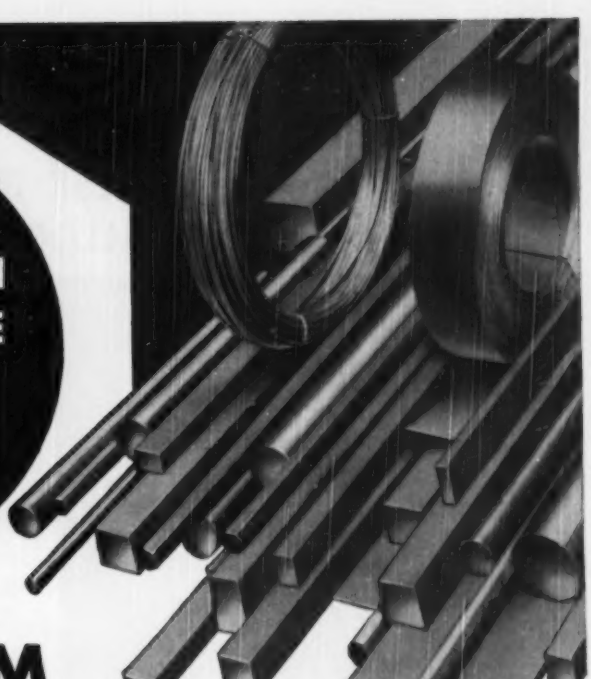

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Zinc-Base Solder*

BECAUSE the world supply of tin is very short there are efforts to reduce the use of tin in solders. For copper alloys and steel a solder alloy is recommended containing 98% zinc and 2% copper. The alloy is manufactured by Hetzel and Co., Nürnberg, and is designated L Zn 98. Its melting point is about 790° F. The author investigated this solder by joining copper-clad aluminum sheets (10 Cu – 80 Al – 10 Cu, the so-called Cupal). For comparison the commonly used solders L Sn 25 and L Sn 40 (25 and 40% tin) were also examined.

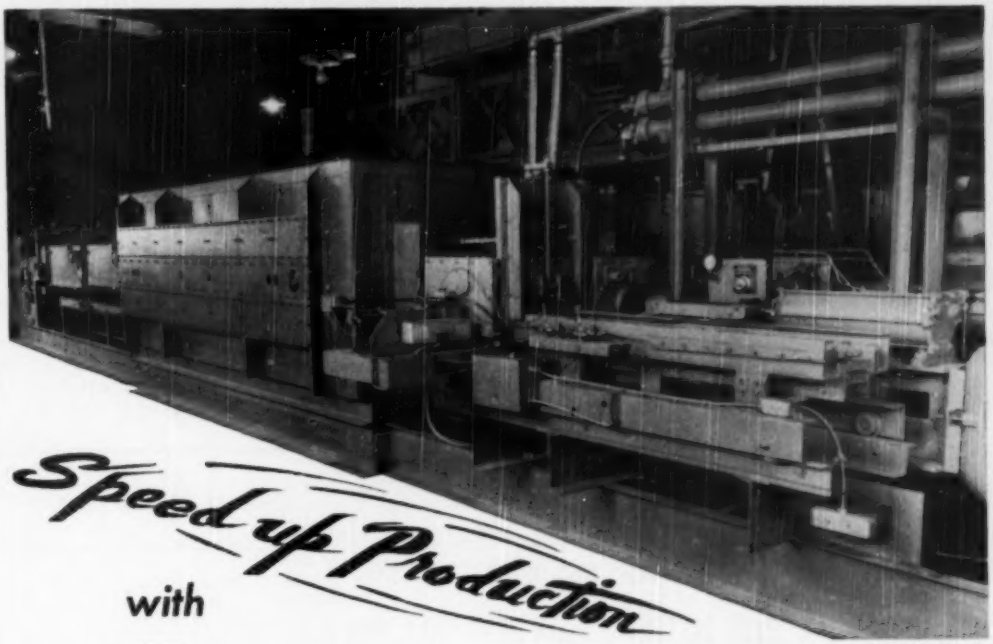
All the soldering was done by using the "AEG Kleinschweisszange" (AEG little welding device). The joints to be soldered come between two carbon resistor electrodes and are electrically heated. With the copper base metal, the solder forms a film of brass, which has proved to be a reliable bond.

Table I — Average Shearing Strength of Soldered Joints in Cupal Sheet

Sheet Thickness (Mm.)	Shearing Strength, Psi.		
	Lap at Joint		
	5 Mm.	10 Mm.	15 Mm.
	Joined With 25% Sn Solder		
1.5	—	—	—
2.0	3555	2702	1991
3.0	4124	3697	3271
	Joined With 40% Sn Solder		
1.5	—	2275	—
2.0	4267	2844	2844
3.0	5120	4267	3556
	Joined With 98% Zn Solder		
1.5	—	2560	—
2.0	4409	3271	2987
3.0	4978	3271	2560

Results of determinations of the shearing strength of soldered joints are listed in Table I. Thinner sheets generally show lower shearing strength than thicker sheets. This fact may be explained by distortion of the joints and length-shearing of the sheets in testing, which is more effective with the thicker than with the thinner sheets. Also, the results show that the values decrease if the amount of joint overlapping increases, probably because of the greater distortion and deformation of the joints. *(Continued on p. 548)*

*Abstracted from "Soldering With Zinc Solder", by F. Trey, *Berg- und Hüttenmänniache Monatahefte*, Vol. 92, December 1947, p. 221-228.



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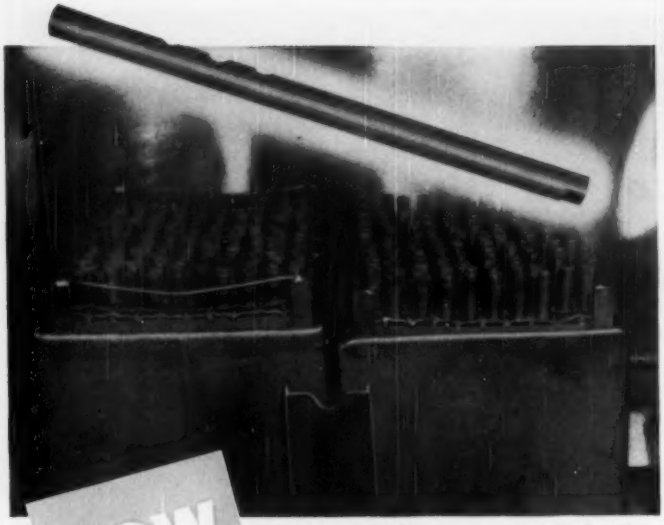

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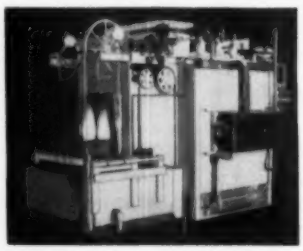

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Zinc-Base Solder

(Starts on p. 546)

In using this new zinc-base solder some special properties have to be considered. For instance, the sheets must not be covered with a thin layer of solder before the joining operation is started, as is usual with tin solder, and the soldered joint should be quenched immediately, to preserve a homogeneous filler alloy.

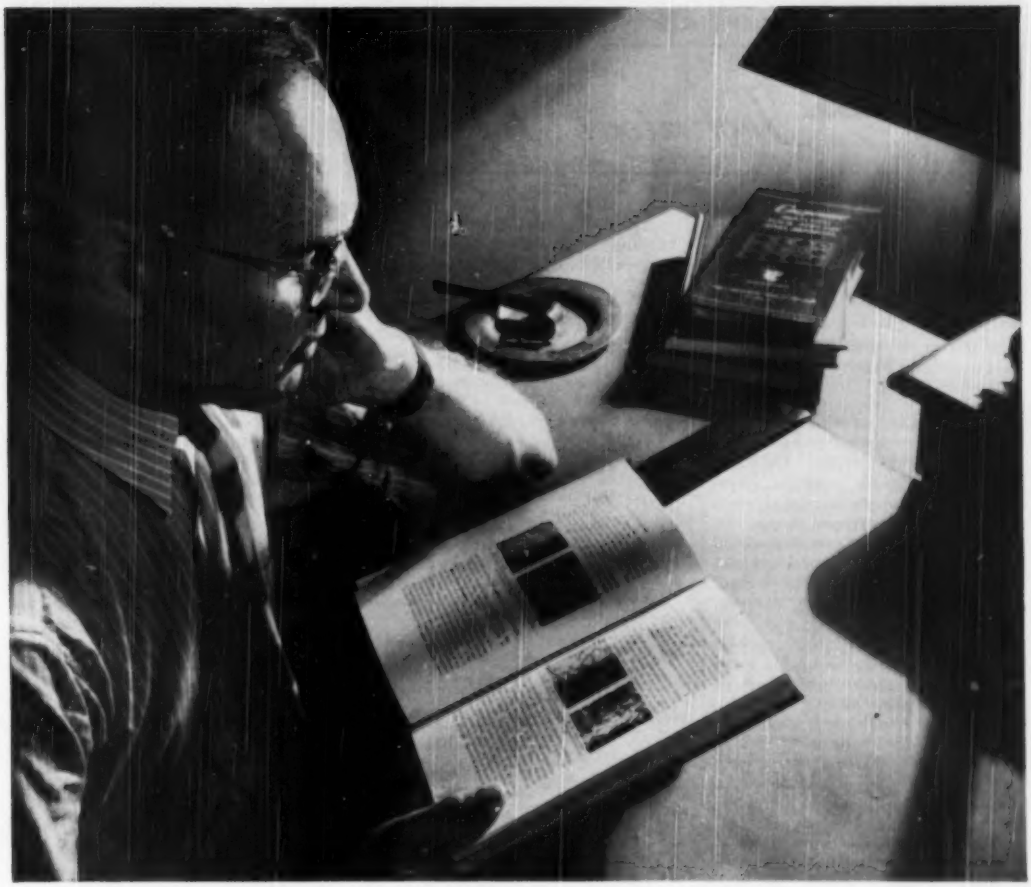
In the opinion of the author, this zinc solder may be substituted for brass brazing alloy, as well as for tin solder. OTTO MIRT

Phase Boundaries*

RECENT criticisms of the X-ray powder method of determining phase boundaries in metallurgical equilibrium diagrams have prompted Professor Owen and Mr. Morris, of the University College of North Wales, to rise in defense of that technique and to claim that the criticisms, especially those of Hume-Rothery and Raynor, are unfounded. Certain objections to the microscopical method are pointed out, and further consideration is given in the light of more recent researches to the behavior of solid specimens when compared with powder specimens after various treatments. Undoubtedly, state the authors, the filing and sieving processes can lead to introduction of impurities, but this can be remedied by careful technique. Decomposition by quenching is just as likely with solid as with powder specimens. On the other hand, the quantitative measurements of the X-ray method are an invaluable criterion of equilibrium.

Work carried out by the authors and their colleagues shows that different crystals in the same large-grained solid specimen can have different lattice spacings even in specimens which one would normally assume to have been annealed to equilibrium. *(Cont. on p. 550)*

*Abstract of "Application of X-ray Methods to the Determination of Phase Boundaries in Metallurgical Equilibrium Diagrams", by E. A. Owen and D. P. Morris, *Journal* of the Institute of Metals, Vol. 76, 1949, p. 145.



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Technical Topics

WELDING STAINLESS ALLOYS

Norman S. Mott
Chief Chemist and Metallurgist
The Cooper Alloy Foundry Co.

In the welding of stainless alloys, four types of composition have to be taken into consideration — the hardenable martensitic straight chromium group; the non-hardenable ferritic straight chromium group; the corrosion resisting chromium-nickel group, and the heat resisting chromium-nickel group. These alloy compositions have, in varying degrees, greater thermal expansion and lower thermal conductivity than carbon steels, and in some instances have carbide mannerisms which affect corrosion resistance.

When the torch flame or arc is applied, the metal is heated to a very high temperature only in the area being welded. The heated metal expands and tends to push out in various directions against the colder surrounding metal, producing severe internal stresses. When the heat source is removed, the resultant contraction produces pulling stresses acting between the cooling and the cold metal. If the metal does not have sufficient ductility to stretch and accommodate itself to these great stresses, cracking will result. This is most prevalent in the lower ductility straight chromium grades. By making temperature gradients as gradual as possible, this danger can be minimized.

In the chromium-nickel corrosion resisting alloy types, a form of grain boundary carbide precipitation occurs during welding. To offset the dangers of intergranular corrosion, these carbides must be put into solution by subsequent heat treatment before the welded metal is put into use.

Difficulties which are involved in welding cast stainless steel can be overcome through the use of pre-welding and post-welding thermal treatments as indicated below.

Alloys for heat resistance applications usually do not require any thermal treatment after welding.

ALLOY	REMARKS
5%Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1650° F. . . . hold for 1 hour, furnace cool to 1350° F., hold for 2 hours, then air cool.
9%Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1350° F. . . . hold for 2 hours, then air cool.
12%Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1350° F. . . . hold for 4 hours, then air cool.
16%Cr	Preheat to 250-300° F. After welding, cool to 250° F. or lower, then heat to 1450° F. . . . hold for 4 hours, then air cool.
18%Cr	Preheat to 250-300° F. After welding, cool to 150° F. or lower, then heat to 1450° F. . . . hold for 4 hours, then air cool.
27%Cr	Preheat to 250° F. or over. After welding, heat to 1650° F. . . . hold for 2 hours, then rapidly air cool. If distortion is feared stress-relieve weld for 1 hour at 1350° F. followed by air cooling.
18-8S	Preheat not required. After welding heat at 2000° F. for 1 hour, then water quench.
18-8SCb	Preheat not required, nor is post heat. However, after welding, it may be stress-relieved at 1650° F. for 2 hours followed by air cooling.
18-8SMo	Preheat not required. After welding heat at 2000° F. for 1 hour, then water quench. Sufficiently ferritic alloys often can be used without post heating.
FA-20	Preheat to 400° F. After welding cool very slowly then heat to 2000° F. . . . hold for 1 hour and water quench.

Available on request

NEWSCAST, a periodical to which Norman S. Mott is a regular contributor, covers news, authoritative information and applications of stainless steel valves, fittings and castings. To be placed on the mailing list, write to The Cooper Alloy Foundry Co., Hillside 5, N.J.

COOPER ALLOY
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Phase Boundaries

(Starts on p. 548) This shows that polycrystalline specimens are really aggregates of individual crystals of different shapes and lattice spacings. Measurements on individual crystals have been made and they show these variations; it is therefore not surprising that results obtained with comparatively coarse-grained specimens are not always consistent.

These local variations may occur from crystal to crystal in a fine-grained solid specimen also, but the effect is smoothed out because the measured lattice spacing is the mean of those of a large number of crystals. Further, if the specimen is simultaneously rotated and oscillated during exposure, the measured lattice spacing could reasonably be expected to be free from complications due to the selective action of incident X-rays which, in a stationary specimen, results in grains of only one particular orientation contributing to the diffraction lines and thereby giving an expansion or contraction effect in stressed specimens. Even for fine-grained solid specimens, anomalous lattice spacings are obtained even after long annealing treatments, and this is attributed to the difficulty of removing strains set up during cold working. This difficulty is overcome in powders, because each particle consists of only a few crystals and they are relatively much more free to assume the equilibrium configuration than is true in solids.

Solid specimens, even after prolonged annealing, cannot properly be regarded as being in a true equilibrium state, and the preparation of metallurgical specimens for microscopical examination is likely to lead to further deviation from equilibrium.

The authors' final conclusion is that when the study of equilibrium conditions is the ultimate goal, the X-ray powder method has decided advantages over any other method, provided that due care is taken to avoid contamination and that observations are made at high temperature as well as on quenched specimens at room temperature. A phase boundary can be determined by the X-ray method from parameter measurements alone, and an accurate determination can be made irrespective of the amount of the second phase present. According to Professor Owen, *(Cont. on p. 554)*

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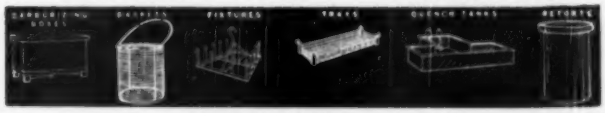

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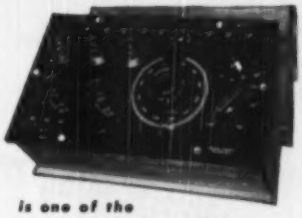

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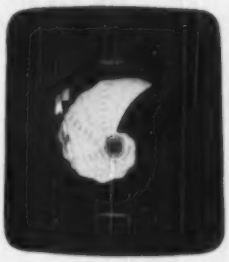

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Phase Boundaries

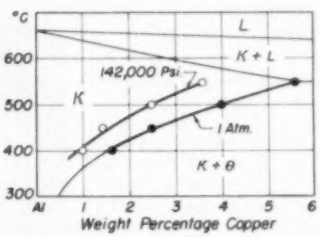
(Starts on p. 548) the X-ray investigator who tries to determine an equilibrium diagram by the X-ray powder method alone is more likely to arrive at a diagram representing the true equilibrium state of an alloy system than the metallurgist who employs only classical metallurgical methods for which solid specimens are necessary. [Needless to say, a combination of other methods with X-ray diffraction is usually desirable, and may be essential. For instance, consider the difficulties in determining the iron-carbon diagram by X-ray diffraction alone.]

Effect of Pressure on Solid Solubility*

THE usual binary phase diagram is determined for use at atmospheric pressure. However, it is well known that pressure has an effect on phase equilibrium. In particular, the influence of pressure on solubility is given by the equation:

$$\frac{dL}{dp} : \frac{dL}{dT} = \frac{\Delta v}{H} T$$

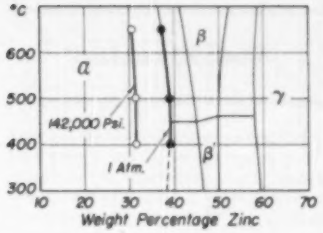
where L is the solubility of the solute, p is the pressure, T is the



temperature, Δv is the volume change produced by equilibrium solution of one gram-atom of the solute, and H is the heat of solution.

In spite of the practical interest in the subject, no experimental determinations of the influence of pressure on solid solubility have previously been made, because of experimental difficulties. These in-

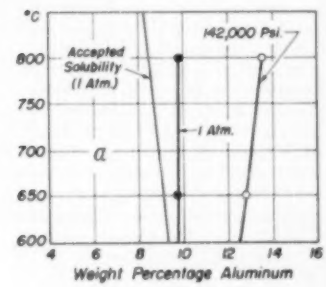
*Abstracted from "Change in Terminal Solid Solubility of Metals Under Hydrostatic Pressure", by M. I. Zakharova, *Doklady Akad. Nauk S.S.S.R.*, Vol. 68, 1949, p. 69-71.



clude the problems of obtaining saturated solutions and of determining the chemical compositions of the solid solutions. In order to obtain equilibrium in a reasonable time it is necessary to work at high temperatures. It was found possible to do this by using a Brinell press containing a metallic hydrostatic compression medium. This procedure permitted a pressure of 142,000 psi. to be exerted for long times on a 6-mm. diameter specimen. Since the growth of a second phase depends on diffusion, it was necessary to increase the soaking time from 2 to 40 hr. in order to produce equilibrium as the temperature was lowered from 800 to 400° C. (1470 to 750° F.). The concentration of the solid solution was determined by precise X-ray diffraction measurements. When the interatomic spacing no longer changed with increasing soaking time, it was concluded that equilibrium had been established.

In the accompanying figures, the author's data have been plotted on the pertinent phase diagrams from the 1948 Metals Handbook.

Whether increasing pressure increases or decreases the solubility is determined by the sign of the volume change term, Δv, in the equation given above. Metallographic study of an aluminum – 4% copper alloy confirmed the X-ray results for that system. The high-pressure, high-temperature equilibrium is retained on rapid cooling to room temperature, but it is gradually displaced on heating at atmospheric pressure.



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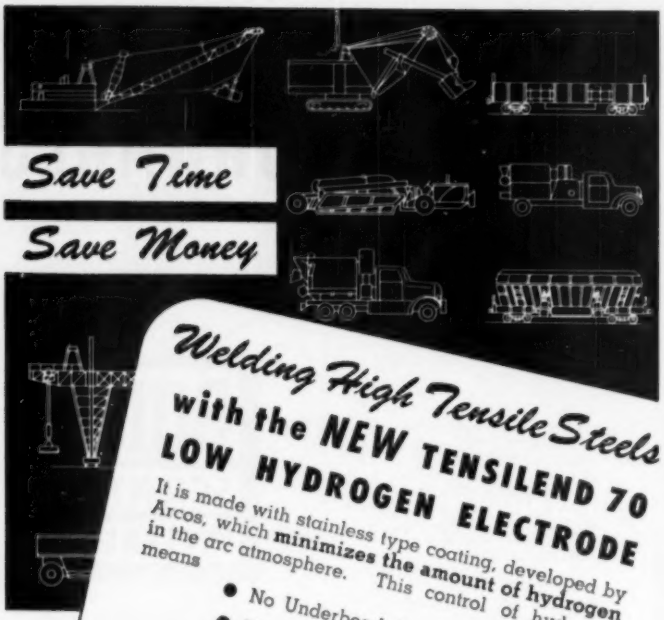

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Stabilization*

IF the continuous cooling of steel is interrupted in the martensite range, transformation of austenite to martensite does not begin immediately on the resumption of cooling, but only after some hysteresis, which is greater the longer the duration of isothermal holding. This phenomenon has become known as stabilization. The author studied stabilization of austenite in eight types of toolsteel with the aid of a sensitive magnetometer that registered the increase in amount of martensite, both during isothermal holding and subsequent cooling.

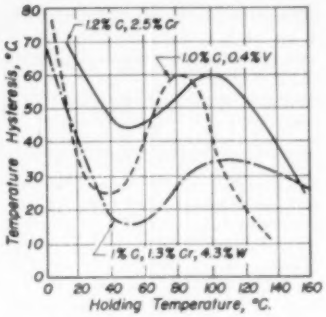

Fig. 1 — Influence of the Holding Temperature on Stabilization of Austenite

As shown in Fig. 1, the hysteresis increases with decreasing temperature of isothermal holding, passes through a maximum, and after some decrease again sharply increases with decreasing temperature of holding in the martensite range. It was also noted that, in a certain temperature interval below M_s, martensite formation takes place at constant temperature. The amount of martensite that forms isothermally increases to a maximum with decreasing temperature, and then falls to zero. Below a certain temperature T_k no isothermal martensite formation is observed for the same duration of holding.

A definite relation is shown between the increase of the martensite phase at constant temperature and the magnitude of the hysteresis during subsequent cooling. Experimental data on the amount of martensite formation during continuous cooling, on the increase in the amount

*Abstract from "The Stabilization of Undercooled Austenite", by P. P. Petrosyan, *Doklady Akad. Nauk S.S.S.R.*, Vol. 59, 1948, p. 1109-1111.

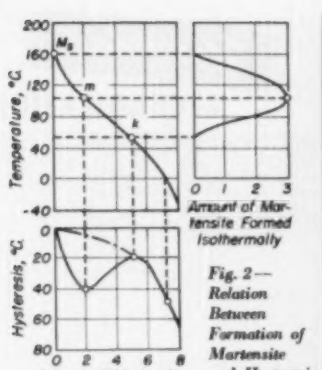

Fig. 2— Relation Between Formation of Martensite and Hysteresis on Cooling

of martensite formed isothermally, and on the magnitude of temperature hysteresis (the delay of transformation when cooling is resumed) were the basis for constructing a set of interrelated curves that have the general appearance of Fig. 2. These graphs show that the maximum and minimum of hysteresis correspond to the temperature of maximum and minimum formation of isothermal martensite, respectively. Thus, in the indicated temperature interval, an increase in the amount of isothermal martensite increases the hysteresis; that is, the hysteresis curve deviates from the hypothetical curve (the dashed line in the lower graph of Fig. 2). The magnitude of the deviation is proportional to the isothermal increase of the martensite phase. *(Cont. on p. 558)*

Table I — Data for Four Steels
T = Temperature of Isothermal Holding (holding time, 5 hr.)
θ = Hysteresis on Later Cooling
ΔM = Amount, Isothermal Martensite

T	Steel U-12		Steel KhVG	
	θ	ΔM	θ	ΔM
150° C.	43	1.0	22	0.5
120	69	2.5	40	2.7
100	67	2.5	30	2.5
75	53	1.4	20	1.6
50	33	0.2	16	0
20	42	0	40	0
0	50	0	63	0
T	Steel Kh-12		Steel Cr-4	
	θ	ΔM	θ	ΔM
150° C.	22	0.5	—	—
120	58	1.3	20	1.5
100	60	1.3	50	2.3
75	52	0.8	54	2.3
50	43	0.2	27	0.8
20	65	0	30	0
0	96	0	80	0

Identification of Steels: U-12, 0.65% C, 4.0% Cr, 1.7% W; KhVG, 1.0% C, 1.3% Cr, 4.3% W; Kh-12, 1.2% C, 2.5% Cr; Cr-4, 1.0% C, 0.4% V.

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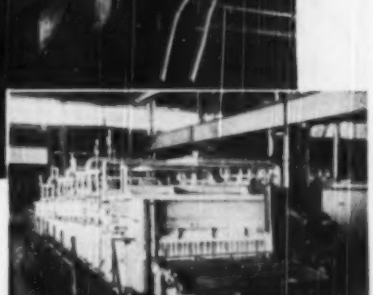
Charging end of furnace, showing billets being raised on furnace chains to inclined loading platform.



Discharge end: hydraulically operated mechanism rises to allow billets to roll out toward piercing machine.

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Stabilization

(Starts on p. 556)

The indicated relation was noted in the kinetic curves of all the steels investigated. Table I summarizes the experimental data for four of the steels.

The relation found between isothermal martensite and the transformation hysteresis on subsequent cooling may have considerable significance in explaining stabilization of undercooled austenite — a phenomenon that has no verified theory at present.

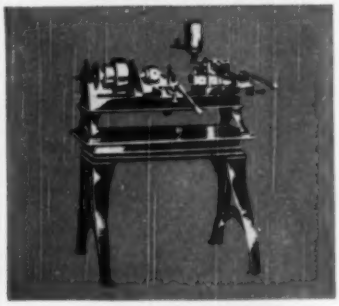
New Zinc Alloy*

ZINC-BASE alloys containing 4 or 10% Al, with small additions of copper and with magnesium contents of the order of 0.05% have been much used in Europe. Higher-aluminum alloys of near-eutectoid (22% Al) composition, while stronger and harder, were found to be unstable and deficient in corrosion resistance. During the period 1940 to 1942, apparently under the pressure of war requirements, an interest arose in Germany for zinc-rich alloys on the aluminum side of the eutectoid point, where the more ductile face-centered cubic solid solution crystallizes. A number of systematic researches were completed, resulting in the development of a zinc alloy containing 32% Al, 3% Cu and 0.05% Mg. The original alloys were compounded from the purest metals available (99.9% Al, 99.99% Zn) and the first two installments of Gebhardt's work describe the characteristics of these high-purity alloys, as extruded and as heat treated.

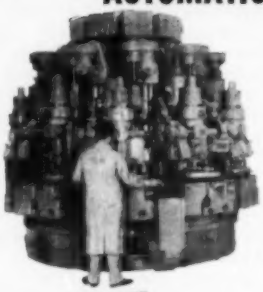
From the very beginning the alloys were prepared on a large scale, yielding billets about 5 in. in diameter and 15½ in. long, which were extruded using a pressure of 1250 tons. (Also about 12 in. in diameter, extruded at 3500 tons.) The conditions resulting in a satisfactory product are described as: superheating the melt (unprotected) to 1290° F. and casting at 1255° F., using a water-cooled cop-

*Abstract from "A Zinc Alloy of High Aluminum Content", by Erich Gebhardt, *Metallforschung*, Vol. 2, 1947, p. 17-25, 57-62, 225-230, 310-320.

Yesterday
MECHANIZATION



Today
AUTOMATION



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per mold. Billets enter the press at 535 to 570° F., while the cylinder is heated at 500 to 570° F.

The matrix cannot be resolved at 400 diameters, but crystals of a Cu-Zn compound are definable.

The characteristics of the raw extruded alloy are: tensile strength, 67,000 to 70,000 psi.; yield strength (0.2% set, carefully determined), 52,000 to 62,000 psi.; Brinell hardness (5-mm. ball, 250-kg load), 125 to 130; elongation in 4 in., 10 to 15%; reduction in area, 35 to 45%; modulus of elasticity, 11,500,000 psi.; density, 4.7; electrical resistivity, 6 microhm-cm.; creep limit, 8500 to 10,000 psi. at ordinary temperature; dimensional changes, less than 0.01% in one month at 122° F. and 0.07% in 17 days at 203° F.

Corrosion resistance, which is gaged for zinc-base alloys by a standardized test for 10 days in steam at 203° F., was found to be just as good as for the usual alloys with 4 or 10% Al. The samples became covered with a dark skin that showed no tendency to peel off and was less than 0.002 in. thick.

Quenching from any temperature above 610° F. homogenizes the alloy (with the exception of the Cu-Zn phase), but in order to obtain rapid hardening at room temperature the metal must be solution treated for 4 hr. above 700° F. and water quenched.

Solution treated, the metal has a hardness of 140 Brinell and its plasticity is somewhat higher than in the raw extruded state. It ages to 192 Brinell in 24 hr. and does not seem to overage at room temperature. At the same time the tensile strength goes up to 94,000 psi., elongation drops to 6% and reduction in area to 17%.

Aging is far more rapid between 165 and 250° F. The high strength can be obtained within the first hour, but ductility drops too much, so that aging must be extended and after 20 hr. at 250° F. one obtains 70,000 psi. tensile strength, 13% elongation and 50% reduction in area. In the standard corrosion test the hardened alloy behaved the same as the raw extruded material. Electrical resistivity and modulus were noticeably lower in the quenched state, but the latter rose from 7,800,000 to 10,000,000 psi. on precipitation hardening.

The author considered the standard corrosion test in low-temperature steam to be too indefinite as an

(Continued on p. 560)

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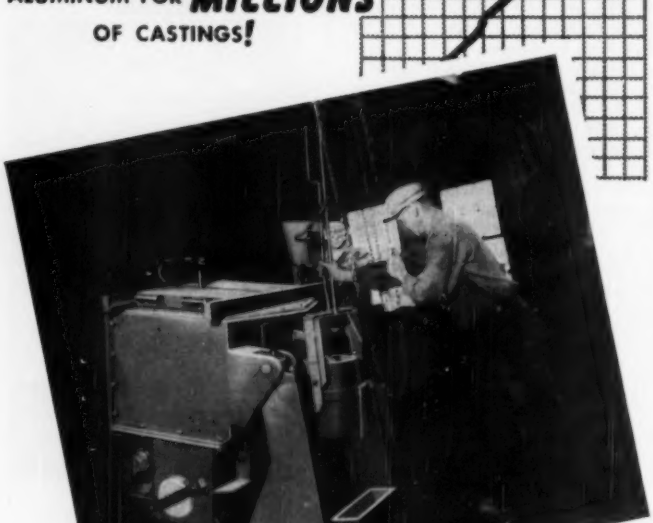

Pouring aluminum alloy from an Ajax Induction Furnace at the Scottdale Foundry, Scottdale, Pa.

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New Zinc Alloy

(Starts on p. 558)

indication of general corrosion resistance, and instituted an extensive program of corrosion tests, including the steam test, atmospheric corrosion, and continuous and intermittent immersion in artificial sea water.

One hundred and forty heats were prepared, partly in the laboratory and partly in the plant, using virgin metals of different purities, as well as a fairly poor grade of zinc (98.5%) and secondary aluminum carrying considerable amounts of iron, silicon, copper and nickel. In numerous melts lead, cadmium and tin were added in order to determine their influence on the corrosion resistance. Comparative tests were made on a 42% Zn brass, on duralumin, hydronalium and the ordinary zinc-base alloys.

Atmospheric corrosion tests lasted for 15 months, after which time the specimens were tested in tension. In between, after 4½ months, the samples were weighed in order to see how far corrosion had proceeded. Microscopic examination indicated that the basic alloy of this research behaved quite well, but samples containing lead corroded to a much greater extent. Duralumin corroded 8 to 12 times more than the pure basic alloy, and such samples as were prepared from secondary aluminum, but contained no lead, tin or cadmium, behaved just as well. None of the samples suffered any extensive loss in tensile strength.

As tensile testing after corrosion did not produce a sensitive indication, the samples tested for 122 days in sea water — continuously or intermittently — were given the more sensitive impact-bending test and the purest alloys were more affected by corrosion than the "contaminated" alloys. Gebhardt concludes, therefore, that except for tin, cadmium and lead no other impurity present in ordinary amounts interferes with the performance of the alloy described in either mechanical or corrosion tests, and that increased amounts of magnesium (up to 0.25%) are likely to neutralize to some extent the deleterious effects of lead.

The article reviewed might be recommended to all industrial researchers as a description of a thoroughly planned and carefully executed program. M. G. C.

Ever stretch a backbone to hold 500 ribs?

Courtesy Rittling Corp.

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Alloy Steel

(Article starts on p. 491)

for more than 50 steel producing companies jointly to meet the war production demands, amounting to 10,000,000 tons of S.A.E.-A.I.S.I. alloy steels per year during World War II, plus another 5,000,000 tons of similar alloy steels made to Army-Navy specifications.

Peacetime Future Demands

With that humility that should characterize all efforts at prophecy, it may be anticipated that

1. The ratio of use of alloy steels in automobiles will gradually decrease—as it has for the past 25 years. (See Fig. 2.)

2. Newer applications to other lines of industry will move forward in greater ratios than the past, because of the imminent introduction of higher pressures and stresses in high- and low-temperature applications to fill the needs of an atomic and supersonic age.

3. It is doubtful whether production of S.A.E.-A.I.S.I. alloy steel will exceed more than 8% of the total ingot production of steel, even if the newer advancements become a reality. (See Fig. 1 and 2.)

4. The field of use of high-strength plates and structurals, as well as other forms of mill shapes, will develop surprisingly within the next 10 years. This will be discussed when a sequel to this article is written by another author in 1960 or later.

5. Newer consuming industries now forming will offset the restricted use of alloy steels that is gradually occurring in the automotive industry.

We wonder what Sir Robert Hadfield, if he were alive today, would say as an epilogue to his prophetic statement made in 1892 before the British Iron & Steel Institute:

"The author cannot but think that the special question of steel alloys or combinations will be eventually found to possess considerable practical importance to the world at large, and perhaps be the means of eventually enabling our civil and mechanical engineers to design and carry out work of a magnitude which, notwithstanding the great strides made during the last few years, even at present are not possible."

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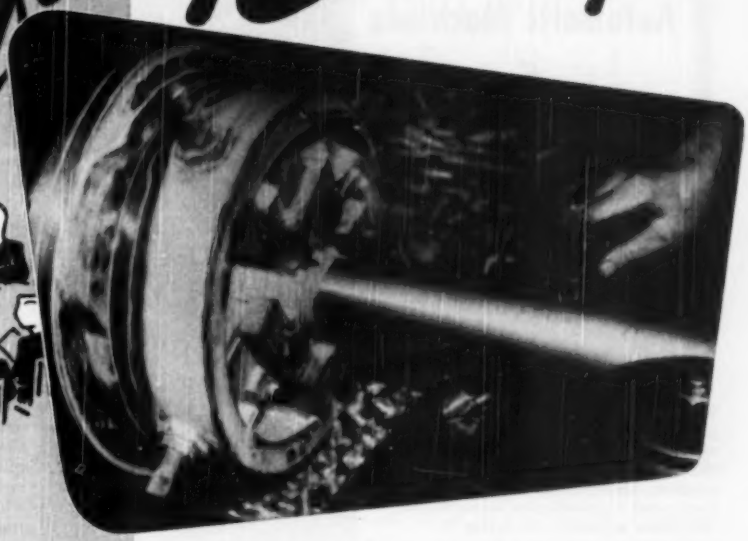

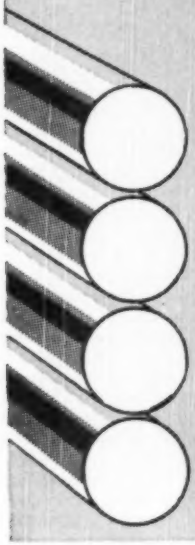

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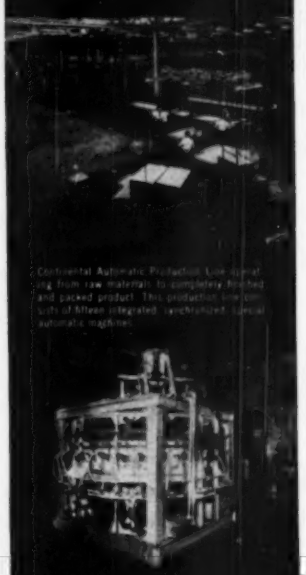

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Metallurgy in South Africa*

SOUTH AFRICAN Iron & Steel Industrial Corp., Ltd., produces 85% of the 835,000 tons of carbon steel, 15,000 tons of ferro-alloys, 7250 tons of low-alloy steel, and 1500 tons of high-alloy steel annually made in the Union of South Africa — figures rising from minute amounts since 1934 to an output that will be increased about 30% next year with the operation of a new plant at Vanderbijl Park. About 335,000 tons of iron castings are also made annually, perhaps half coming from remelted scrap, the other half from new pig iron. About 1,500,000 tons of coking coal is mined in Natal; most of the coke is made in beehive ovens. The ash is so high (16 to 18%) that the silica and alumina entering the blast furnace with the iron ore must be closely limited. The iron ores are therefore of exceptionally high grade by outside standards — anything with less than 62 or 63% iron must be concentrated! Some concentrates contain up to 66% iron. This impure coke and its low crushing strength give special interest to proposals for ore smelting based on low shaft heights, oxygen enriched blast (or a mixture of O_2 and CO_2 to prevent excessive hearth temperatures) in a closed gas cycle. Power costs are low, which indicates that metallurgical oxygen should be cheap.

Great quantities of chromium "ores" are available, but they are so high in iron that a high-chromium ferro cannot be made by direct smelting, nor are the ores suitable for a high-grade refractory. Furthermore, there is little soda ash available for the production of chromates for the chemical, tanning and electroplating industries. Research has been organized to seek a leaching process for these chromium ores that will produce an electrolyte either for deposition of metal, or for oxidation to chromic oxide, or both.

"The Union has followed a rather suicidal policy in exporting

(Continued on p. 566)

*Extracts from "The Utilization of Raw Material in the Ferrous Metallurgical Industry in the Union of South Africa", by T. J. W. Jorden, *Engineering & Chemical Digest* (Johannesburg), Vol. 2, 1950, p. 15.

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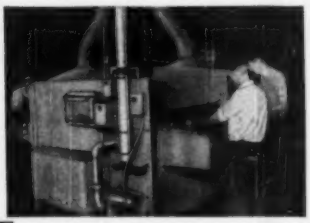

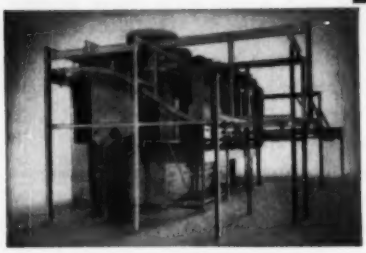

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South Africa

(Continued from p. 564)

its rather limited supplies of high-grade manganese ore, whereas its conversion in this country to ferro-manganese would have enhanced its value sixfold." The very large reserves of low-grade manganese ore will probably require a chemical treatment, yet to be discovered, that is better than the present use of a sulphuric acid leach. (Sulphur must be imported.)

Beryllium*

DURING THE WAR the Siemens-Halske fluoride process of extracting beryllium was superseded in Germany by the Degussa chloride process, and in Italy by the Sappi modified fluoride process.

In the **Degussa chloride process** the ore (mineral beryl) is finely milled and then mixed with 50% by weight of calcium oxide. This mixture is fused at 2700° F. (in a gas-fired rotary furnace, 3.5 ft. diameter by 6 ft. long), quenched and remilled. The dry clinker is treated with sulphuric acid, the aluminum and iron sulphates in the leach being subsequently separated by precipitation, and beryllium hydroxide precipitated from the filtrate by ammonia, dried, and then calcined to beryllium oxide at 1800° F. in a gas-fired kiln. The beryllium oxide may be used *(a)* for the production of beryllium chloride for electrolysis, *(b)* as raw material for reduction to alloys, *(c)* for further purifying for manufacture of refractories.

For the electrolytic process, dry beryllium oxide mixed with charcoal and tar is briquetted and fired at 1475° F. These carbonized briquettes are placed as resistors in an electric arc furnace and exposed to chlorine gas at 1300 to 1500° F. The condensed chlorides are further purified by heating in an atmosphere of hydrogen at 900° F.

(Continued on p. 570)

*From Report No. 25, British Intelligence Surveys, "The Nonferrous Metal Industry in Germany, 1939-1945", procurable for 90¢ from British Information Services, 30 Rockefeller Plaza, New York City 20.

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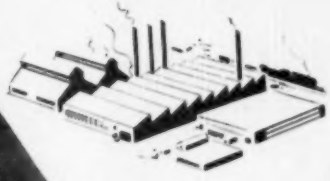

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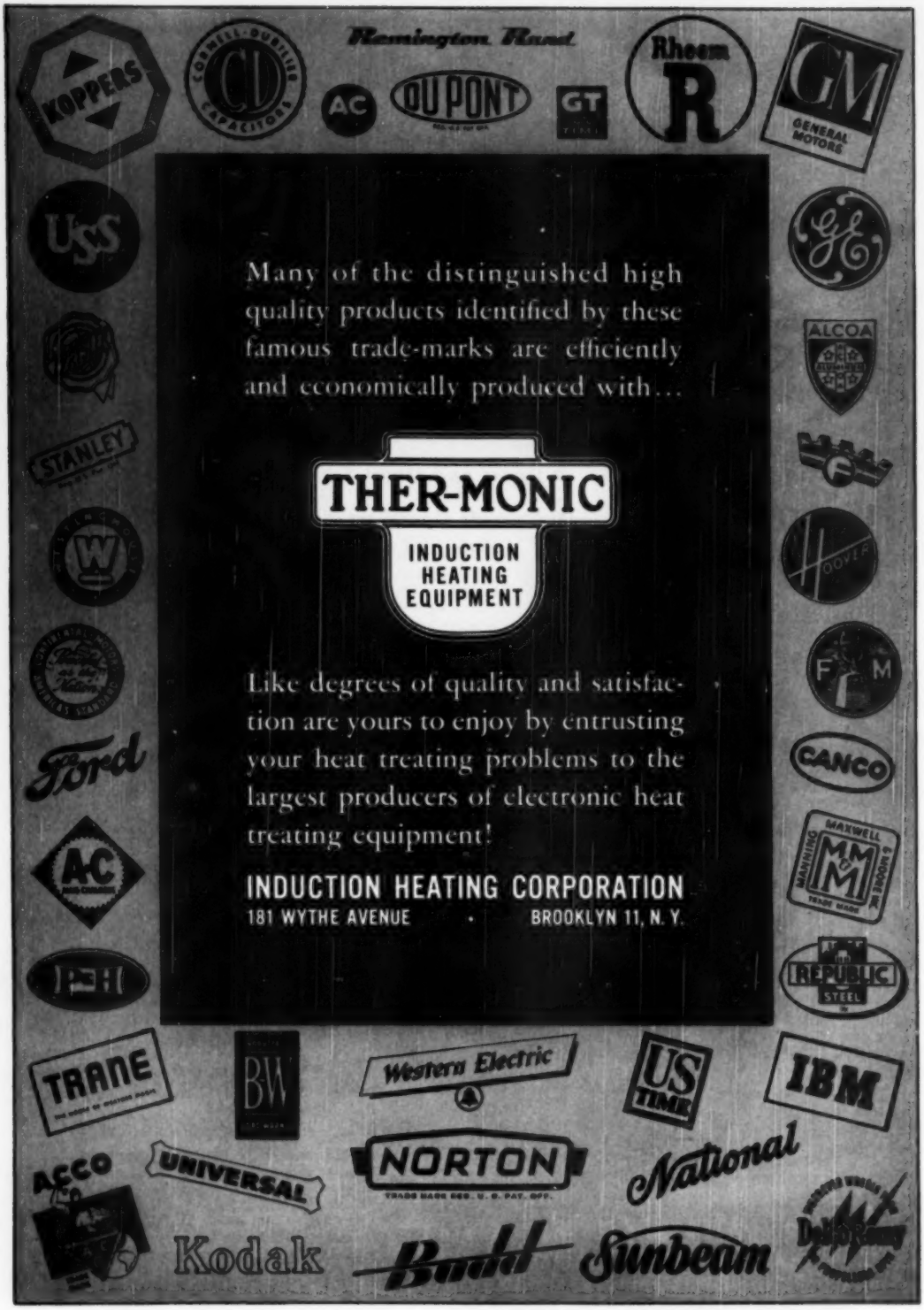
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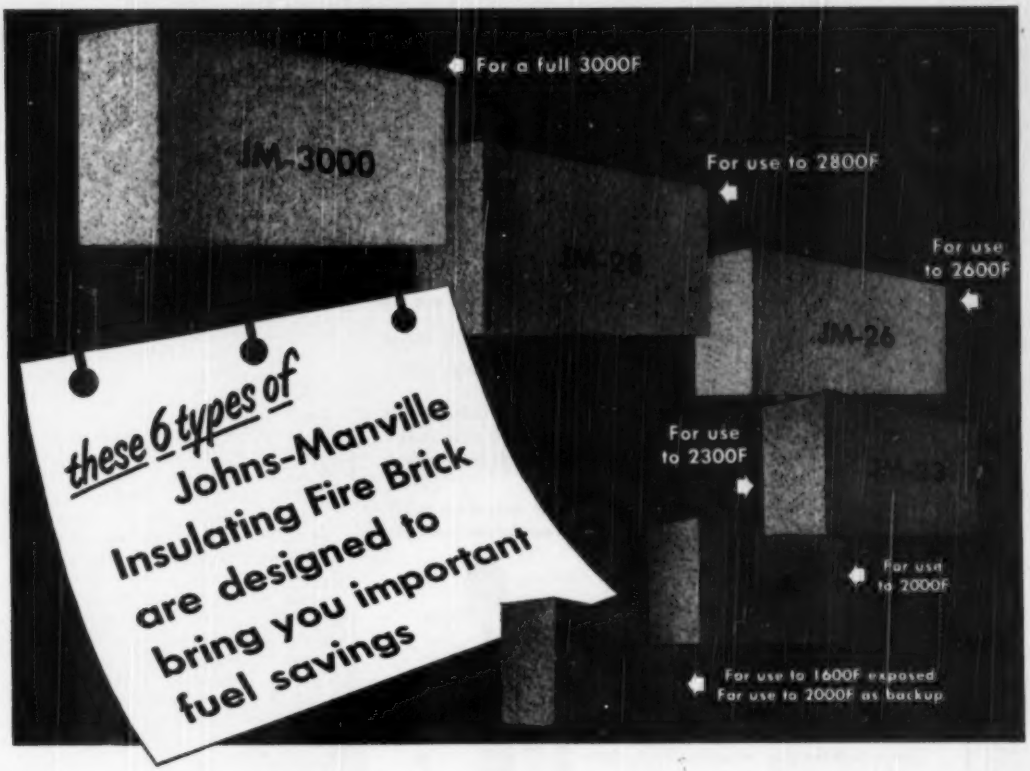

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Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	130	200
Cold Crushing Strengths, psi	70	115	170	190	190	400
Linear Shrinkage†, percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F †	0.5—0.6 at 2000 F	0.5—0.6 at 2,000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.37	1.47	2.31	2.52	3.00	3.55
2000 F	—	1.72	2.70	2.83	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

†24-hr. simulative service panel test for JM-3000; 24-hr. soaking period for other brick. *Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures. Note: Above tests are in accordance with A.S.T.M. tentative standards.

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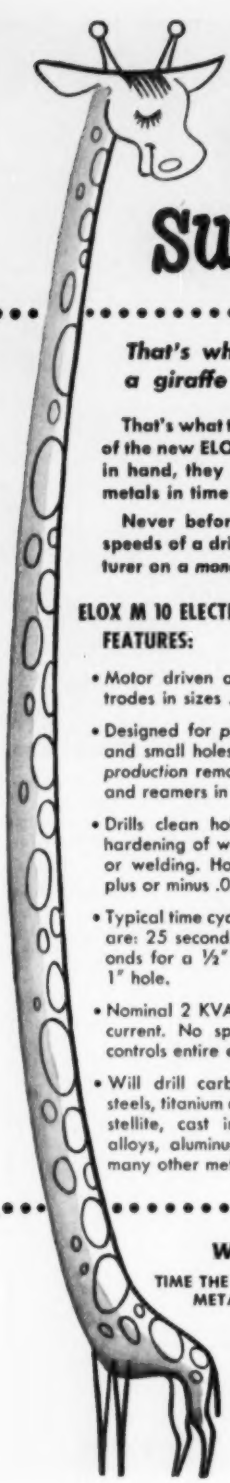

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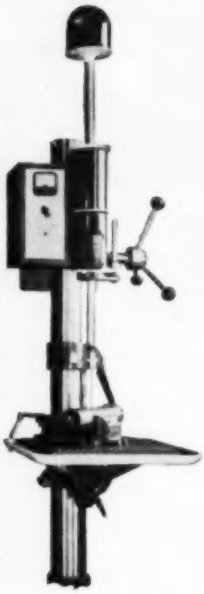

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Beryllium

(Starts on p. 566)

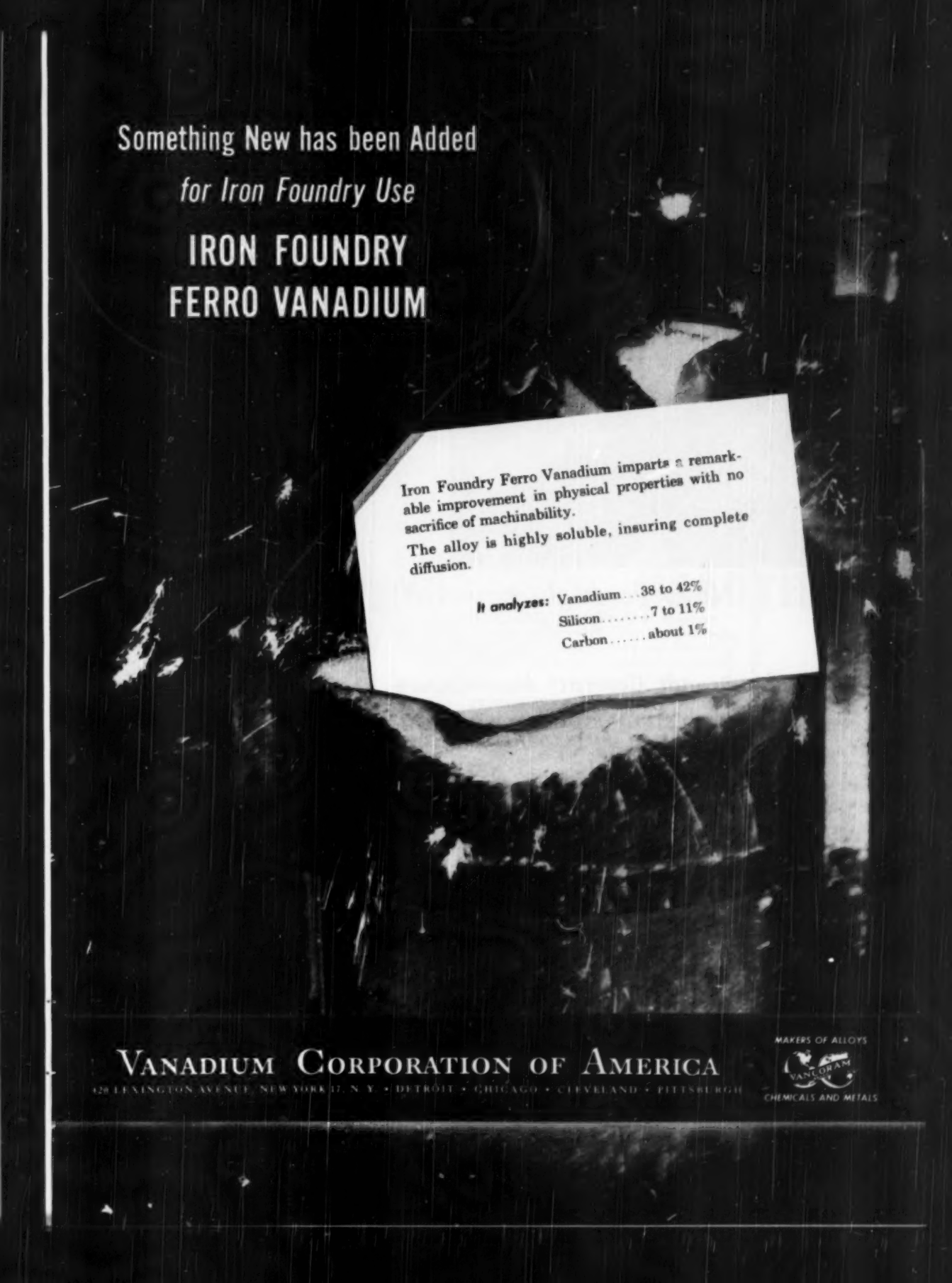
The electrolysis of beryllium chloride (to which 56% of sodium chloride is added) is carried out in a resistance-heated nickel crucible (20 in. diameter and 27 in. deep) at 5 to 9 volts and 500 amperes, the anode current density being about 40 amperes per sq.in., and the temperature 675° F. The nickel crucible acts as the cathode, the anode being a 2-in. graphite rod. The cells operate in series of five, the charge being siphoned from one crucible to another every 24 hr. Production is about 12 lb. from 5 cells each 24 hr. The beryllium flakes, which are scraped from the cathode, have a purity of 99 to 99.4% and may be used for further purification or alloying.

Sappi Process—The essential stages of the Sappi process are as follows: Finely ground beryl, mixed with 50% by weight of acid sodium fluoride, is baked at 1100° F. and leached in a solution of potassium permanganate. Beryllium hydroxide (obtained by treating the liquor with sodium hydroxide) is dried, milled, mixed with acid ammonium fluoride and calcined at 710° F. Crude beryllium fluoride is reduced with magnesium in a high-frequency furnace at 2100° F., in the presence of either aluminum or copper, thus producing the type of alloy desired.

The cost of producing beryllium alloys by the Sappi process, in spite of its apparent simplicity, appears to be higher than that of the Degussa process.

Metal and Alloys—Pure beryllium is obtained from beryllium flakes, by heating pressed briquettes (produced from metal previously washed and pickled in nitric acid and caustic soda solutions) in a beryllium oxide crucible and hydrogen atmosphere. This material is remelted in a resistance furnace (molybdenum wire resistors) under a vacuum of 10^{-3} mm. of mercury, the purity of the metal finally obtained being of the order of 99.8%.

Temper alloys were made by *(a)* adding beryllium flakes to molten base metal (loss in beryllium is of the order of 10%), *(b)* reducing beryllium oxide in an arc furnace, *(c)* the Sappi process. As an example of working the second method, the following data are given: *(Continued on p. 572)*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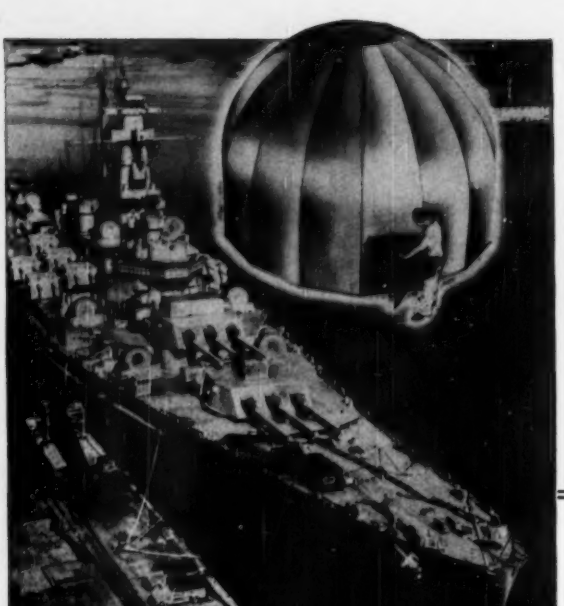

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Beryllium

(Starts on p. 566)

A charge consisting of 40 lb. beryllium oxide, 20 lb. carbon, 45 lb. copper (or copper oxide) and 70 lb. powdered slag (from the previous process) is added to a 275-lb. bath of molten copper. The reduction is carried out in a three-phase, carbon-lined, tilting arc furnace operating at 40 to 70 volts, and absorbing 250 kva.

For melting beryllium alloys and the production of beryllium ingots, vacuum melting and pouring furnaces were used. These were usually of the 1500-cycle induction type, having a capacity varying between 45 lb. and 4 tons, and which are maintained at a vacuum of 0.5 to 2 mm. of mercury.

Ingots of beryllium-copper are cast at very slow speeds, at temperatures between 1650 and 1690° F.; after a preliminary forging at 1375° F. they are hot rolled. Pickling was for 2 hr. in hot 20% sulphuric acid, followed by a 5-sec. dip in cold concentrated nitric acid, a rinse, a cold dip for 30 sec. in 50% hydrochloric acid, another rinse, a dip in a potassium dichromate solution, and a final rinse in water.

Uses and Applications — The main applications of beryllium alloys were for springs, bearing bushes, spark-free tools, membrane disks for instruments, and valve guides.

Small additions (less than 0.006%) of beryllium to magnesium casting alloys were sometimes made to prevent oxidation. With such additions the protective sulphur added to the molding sand can be reduced to 1%, and boric acid may be omitted completely. To prevent grain coarsening effects, small additions of zirconium were made.

An alloy containing 0.2% beryllium, 0.5% manganese, 1% silicon, 0.3% magnesium, 0.5% titanium, remainder aluminum was used for air-cooled cylinder heads.

Aluminum-base alloy pistons coated with beryllium showed a high resistance to wear. The manufacture was still in pilot stage.

Platinum-beryllium alloys were used to replace platinum-iridium alloys.

Thin X-ray windows were made by stamping beryllium flakes, and thicker windows made by grinding beryllium ingots.

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175	325	650	1200	1750
188	338	700	1250	1800
200	350	750	1300	1850
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238	375	850	1400	1950
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Surface Defects in Steel Ingots*

THE Ingot Surface Subcommittee of the B.I.S.R.A. is engaged in a comprehensive study of the nature of surface and subsurface defects in steel ingots, and the effect of such defects on the quality of semi-finished and finished products. All of the usual ingot types — rimmed, semikilled and killed — are included in the investigation. Part I of the report reviews the problem and presents conclusions based on the work thus far; Part II contains detailed supporting data for the conclusions submitted in Part I.

Part I — Review of the Problem — Major ingot cracks are described as those resulting from rupture of the ingot skin during solidification of steel in the mold. Such cracks often become apparent only after the ingot has had a few passes in the blooming mill; however, in the opinion of the subcommittee ingots of plain carbon steel that are free from cracks cannot be cracked during blooming mill rolling within normal limits of rolling temperatures and rolling reduction. This statement, which by implication places responsibility for major cracks with the steelworks, probably will not be accepted without reservation by most steel plant operators. However the authors point out that cracks may be aggravated in the blooming mill by low temperatures and heavy reductions.

For semikilled ingots in the carbon range between 0.15 and 0.25% the committee states that, other things being equal, the tendency toward cracking is reduced as the volume of distributed blow holes increases. By inference, the closer the semikilled ingot approaches the effervescent type the freer it will be from major cracks. In practice, this does not seem to be a feasible objective because deoxidation must be sufficient to prevent excessive gas evolution and bleeding in the mold. Tapping temperatures recommended are the minimum necessary to give a ladle free or almost free from skull; the taking of bath temperatures in the *(Cont. on p. 576)*

*Abstracted from the First Report of the Ingot Surface Defects Subcommittee, British Iron and Steel Research Association, *Journal of the Iron and Steel Institute* (London), May 1950, p. 41.

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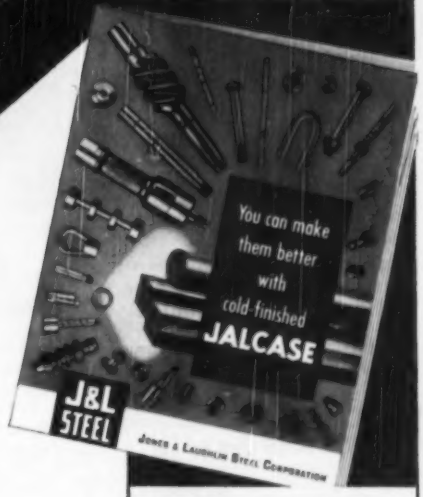

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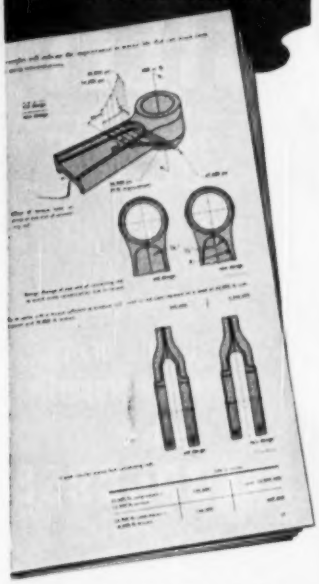

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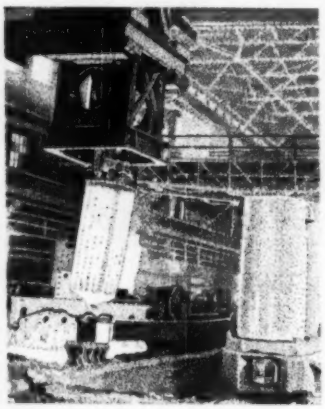
Ingot Defects

(Starts on p. 574) production of this grade is strongly recommended. Slowest practicable teeming speeds are suggested for semikilled steels. The use of molds at temperatures above 212° F. is said to be undesirable, a conclusion with which American operators would certainly agree in principle, although the objective is not easily attained in the face of high tonnage demands. Tar or lacquer mold coatings are said to increase cracking tendencies in semikilled steels, although coating the bottom third of the mold is admittedly desirable to reduce splash defects.

In both semikilled and killed steels considerable evidence is available to show that cracking increases with higher sulphur content and the committee stresses the importance



of taking all possible steps to reduce sulphur in raw materials and in melting.

For fully-killed ingots, mold coatings of tar or lacquer are said to be highly beneficial even though of questionable value for rimmed or semikilled steels. Special teeming arrangements, such as multiple-nozzle tun-dishes, or bottom-pouring are recommended as highly efficacious in avoiding cracks in fully-killed steels. While these suggestions may be metallurgically meritorious, in the United States the cost and inconvenience frequently outweigh the advantages gained.

Cracks in rimming steel ingots are rare; in fact, the grade is so resistant to cracking that the authors

(Continued on p. 578)

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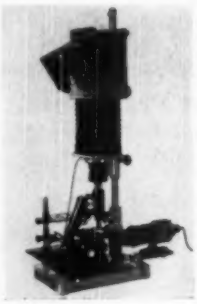

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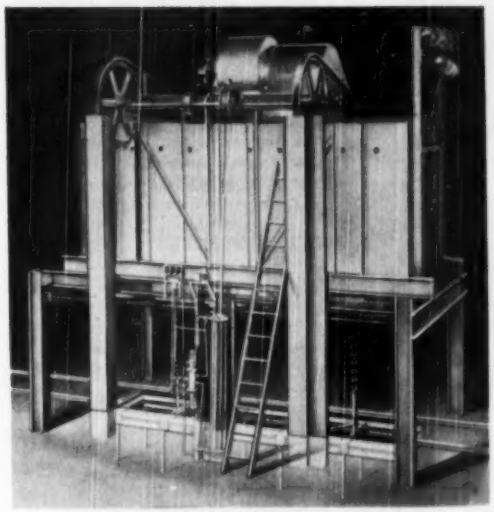

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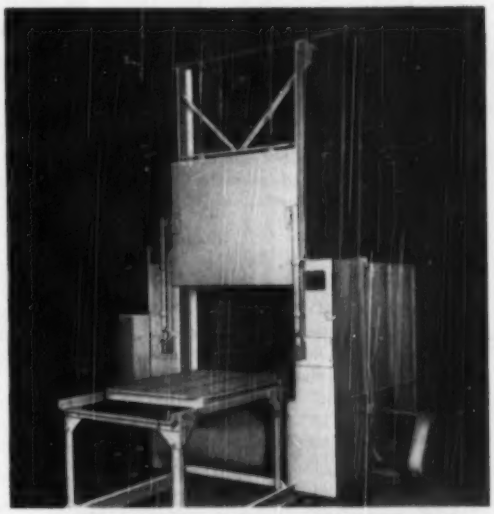

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ACCO

Ingot Defects

(Starts on p. 574)

state that badly worn molds may be used without any ill effect.

The influence of corrugated or fluted molds on surface quality has been subject to some difference of opinion; some firms report that with better control of bath temperature the use of corrugated molds is no longer advantageous.

The location of blow holes in semikilled ingots is most favorable with heavier additions of deoxidizer but the best over-all results seem to be obtained by keeping mold additions to a minimum and expediting the ingots through the stripper yard and soaking pits. For rimmed steels slow teeming speed is recommended and if small nozzles are not practicable, then bottom pouring. Current American practice, at least for large ingots, seems to favor rapid teeming of rimmed ingots; bottom pouring is rarely if ever used for rimmed steels.

Additions of iron oxide (fine roll scale) are suggested to improve the mold action of rimming steels. No mention is made of sodium fluoride, which has been extensively used for the purpose in the United States.

In discussing the general question of mold coatings the committee concludes that for killed steels dehydrated tar produces results as good as can be obtained with any.

The effect of condition of the mold surfaces upon surface quality of the ingot is a debatable one, and some evidence indicates that crazing of the mold faces may actually be beneficial rather than deleterious. In general the committee favors molds with relatively thin walls so that they may be scrapped economically before the surface has deteriorated to a questionable extent.

For future work the committee proposes extensive studies of pertinent factors in melting and rolling, including such items as mold coatings, teeming speeds, effects of deoxidizers and additions, effect of cold and hot charging in soaking pits, and effects of various rolling practices.

Part II — Experimental Evidence — Supporting data from the various member companies are presented to substantiate the conclusions reached in Part I. Most of this information need not be discussed here, although a few interesting points may be

(Continued on p. 580)

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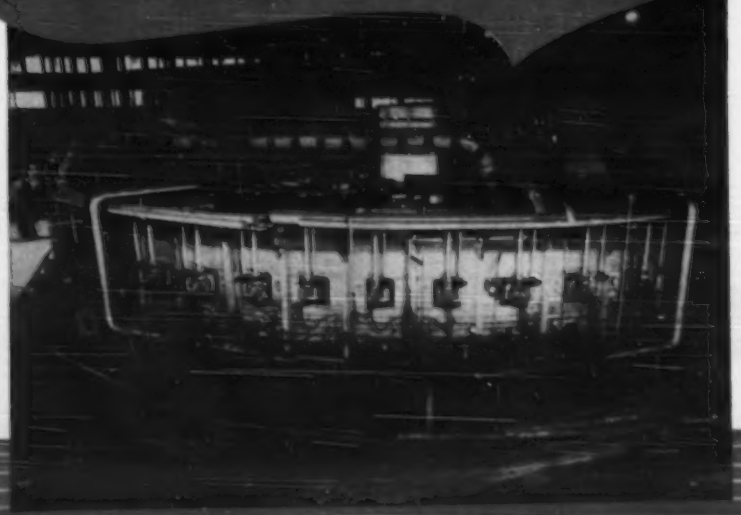
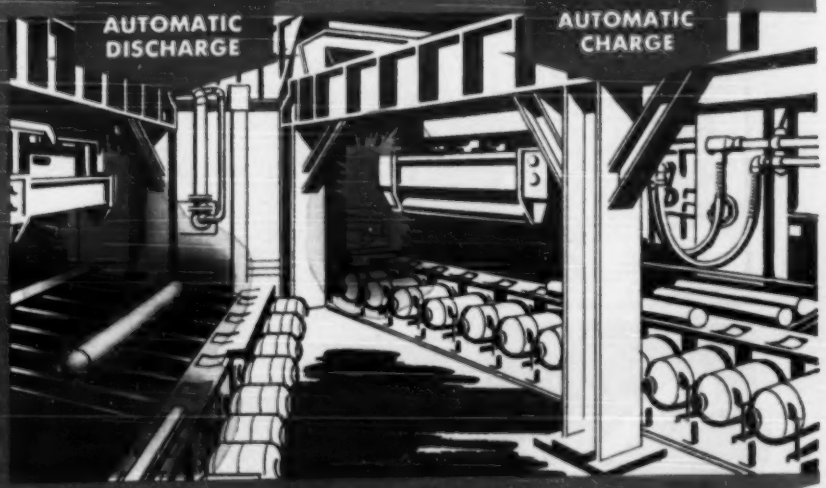
. . . are now heating round or square bars to forging or rolling temperatures with billet weights up to 5000 lbs. No operating labor required for charging or unloading. The entire operation is automatic.

A recent installation is shown below. The automatic charging and unloading equipment is illustrated on opposite page.





Note These Outstanding Features!

1. Bars are charged and discharged automatically, eliminating all labor.
2. Furnace is operated under automatic control of time, temperature and pressure, permitting constant duplication of heating pattern, scale condition and fuel economy.
3. Bars are spaced apart on the furnace hearth, exposing up to 90% of bar surface to furnace gases.
4. Bars are preheated by waste gases with resultant reduction in fuel consumption.
5. Special Hagan Station Switch permits charging new bar lengths on different heating rate while bars are still being unloaded on previous setting, thereby decreasing mill shut-down time.
6. Charger and unloader grips can be adjusted within a minute for changes in bar lengths.

Hagan Rotary Furnaces are sized to suit individual production requirements.

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cleans metal parts, removes rust, scale, grime, dirt, paint, etc., in a few seconds. Ideal unit for producing clean, smooth surface on pieces up to 60" x 36".

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uses liquid blast, eliminating dust, and reduces costly hand polishing, cleaning and finishing of molds, dies, tools, etc. Removes scale, discoloration and directional grinding lines, prepares surfaces for plating and coating. Holds tolerances to .0001".

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Ingot Defects

(Starts on p. 574)

mentioned. A chart is included showing the combined effect of tin and copper on hot shortness determined by a bend test on mild steel at 1740° F. Residual tin, even in small amounts, appears definitely to contribute to the hot shortness of copper-bearing steels.

Studies of the influence of mold life on surface are summarized and there seems to be very little evidence to indicate that worn molds have any undesirable effect. In one plant making steel for seamless tubes it was found that molds could be used safely as long as they could be stripped from the ingot, regardless of the degree of crazing, and molds are now discarded after 200 heats.

In general, the mold life figures cited seem high in comparison with American practice; however, the data probably reflect slower rotation in British plants and possibly higher mold-to-ingot weight ratios.

S. FEIGENBAUM

Metallography With Electron Streams*

IT IS COMMONLY known that the magnifying power of ordinary microscopes using light rays is limited by the wave length of the light, and that this limitation is hurdled when electrons comprise the stream of energy. A prime question now arises, "What is the limiting resolution of the electron microscope, assuming proper instrumental equipment?" (Blue light is capable of resolving particles of 1750 Angstrom units; the ultraviolet microscope 800Å or a particle of about 275 atoms diameter. A particle of 800Å is 0.000008 cm. in diameter; in other words, 300,000 to the inch.)

D. Gabor has proposed a device wherewith an individual atom (3Å ±) would be resolved with an electron microscope. *(To p. 582)*

*Summary of papers in a symposium on Metallurgical Applications of the Electron Microscope, organized by the Institute of Metals (Great Britain), and held in London on November 16, 1949.

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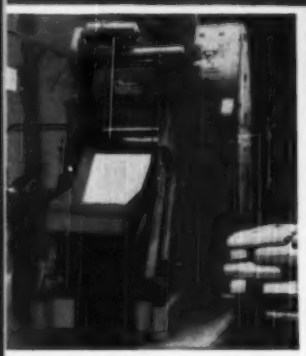

SHOWN INSPECTING RADIATOR PARTS BEFORE AND AFTER CLEANING, C. N. Deubner and Floyd Wells of Yates-American Machine Co. agree: "ROTOBLAST saves money!" Five old-style machines have been replaced by the one ROTOBLAST Barrel shown in the smaller photo. Cash savings each year total more than $5000—proof ROTOBLAST is economical!

Read how manufacturers save money with Pangborn ROTOBLAST*!

Authentic cases in our files *prove* Pangborn ROTOBLAST *saves money* on blast cleaning. For example, take this performance at Yates-American Machine Co., manufacturers of high-quality heat transfer products. Since ROTOBLAST went into operation they have saved more than $5000 a year on blast cleaning!

Other Pangborn users report equally impressive annual savings of five, ten, eleven thousand dollars *and more* when ROTOBLAST takes over a blast cleaning job. Throughout industry, for companies like General Electric, General Motors, Ford . . . ROTOBLAST saves time and labor, and keeps cleaning costs low *without sacrificing quality!*

WHAT ABOUT YOUR PLANT?

If you clean castings, forgings or heat-treated parts, and if you want to save time, money and manpower . . . find out about ROTOBLAST. There's a standard Pangborn Table, Barrel, Room or Table-Room designed for every cleaning job. To get specifications, descriptions and full facts, write for Bulletin 214. Just address: PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md.

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SAVES SPACE: *In many cases, one ROTOBLAST machine replaces five or more old-fashioned machines, requires less space.*

SAVES TIME: *Cases on record prove ROTOBLAST can cut cleaning time up to 95.8%, compared with old-style methods.*

SAVES POWER: *Modern ROTOBLAST uses but 15-20 h.p. compared to old-fashioned equipment requiring 120 h.p. for same job.*

SAVES TOOLS: *On work cleaned with ROTOBLAST, cutting tools last up to 2/3 longer because no scale is left to dull edges.*

. . . and these savings mean INCREASED PROFITS for you!

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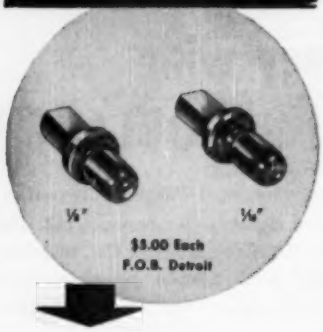

For dependably accurate hardness testing, every part of your testing equipment must be designed by experts. CLARK Hardened Steel Ball Penetrators are designed to give the most accurate possible results in the testing of soft metals such as unhardened steel, cast iron, brass, bronze, and similar metals and alloys. They are available in 1/16" and 1/8" diameters at $5.00, and in 1/4", 1/2", 3/4" and 1" diameters at slightly higher prices. Specify CLARK Steel Ball Penetrators for more accurate "Rockwell" testing.

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Ultramicroscopy

(Starts on p. 580) but with present equipment 25 to 30Å is exceptionally good, and 200Å is the best one expects with replica techniques. This is not capable of resolving a crystallization nucleus (possibly about 5-atoms diameter) but might detect the larger Guinier-Preston zones formed during the aging of aluminum-copper alloys. (Guinier-Preston zones are aggregates on crystallographic planes, named after their discoverers and first observed by X-ray diffraction studies; they are very thin plates wherein the concentration of copper is higher than in their surroundings.)

In electron microscopy the limiting factor is not in the instrument but in the means by which metallic structures are made available to inspection. At present, a typical metallographic investigation can't be carried out with any degree of ease. The replica techniques do not allow a rapid scanning of a large area at low and high power, as can be done with the optical microscope. The recently developed three-stage electron microscope (one having a series of electrostatic or electromagnetic "lenses") has solved part of this problem by providing quick change from magnification well below that attainable with the optical microscope to one of very high magnification, thus enabling a metallographer to correlate a familiar structure with its appearance at high magnification.

One advantage of the electron microscope is the exceptional depth of focus, enabling the study of etch pits, the "block" structure revealed by deep etching, and fracture surfaces.

Technical problems in metallurgy which may be studied by the electron microscope include the hitherto irresolvable constituents of hardened and tempered steel (such as fine sorbite, troostite, upper and lower bainite, alpha and beta martensite) and the precipitates in age hardenable alloys. Grain boundary films and minute insoluble particles are, of course, open to critical study.

Fundamental metallurgical questions of long standing are now attracting attention. The presence of amorphous metal on slip planes

(Continued on p. 586)

Automatic
"STRAIGHT-LINE"
TEMPERATURE CONTROL
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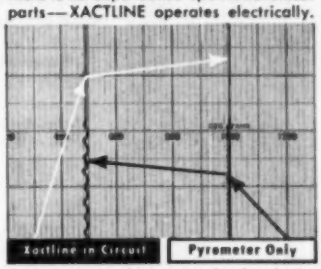
Undershooting

Are you going to continue to put up with that troublesome overshooting and undershooting inherent in your conventional pyrometer control — especially when it is so easy to eliminate that sawtooth effect?

Put XACTLINE in the control circuit. XACTLINE anticipates the temperature changes — before they occur. And too, it nullifies the varying amounts of thermal lag, residual heat, and mechanical lag — producing a short on-off cycle resulting in "Straight-Line" temperature control. This performance is possible because there is no dependence upon mechanical parts — XACTLINE operates electrically.



Exact reproduction of temperature chart for a heating process showing the comparison of the "Straight-Line" temperature control produced by XACTLINE and the saw-tooth curve obtained with only conventional control.

XACTLINE is applicable to any indicating or recording pyrometer control of the millivoltmeter or potentiometer type. It should be used wherever close temperature control is required — any type of electrically heated oven, furnace, kiln, injection molding machine, and fuel-fired furnaces equipped with motor-operated or solenoid valves.

XACTLINE is a complete unit. No adjustment or coordination with the control instrument is required regardless of the size of the furnace, length of the heating cycle, or size of the load. Installation is very simple — can be either flush or surface mounted.

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TYPE AD 502

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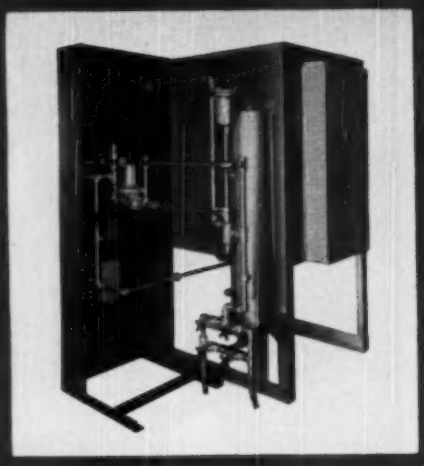

PROVIDES HYDROGEN ATMOSPHERE AT 80% SAVING

THIS latest Hayes development is the answer to customer demand for a Dissociator of the same high quality and efficiency as "Certain Curtain" furnaces. It provides dry and oxygen-free hydrogen atmosphere at about 20% of the cost of bottled hydrogen. Resultant atmosphere is ideal for annealing, sintering, bright annealing of stainless steels, particularly in the radio tube industry, and other operations done in Hayes "Certain Curtain" LA, LAC, BA and BAC Furnaces. This newest Dissociator has a marked increase in efficiency, giving a higher percentage of dissociation with less mass of equipment to be heated; for example, we have done away with heavy cast retort and are now using a tubular multi-wall, long-travel coil, and this can be removed by individual separable connections without welding. All but the smallest sizes operate from either liquid or vapor ammonia supply. Furnished with any desired selection of high quality control instruments.

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- Catalyst unit replaceable without welding.
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- Rectangular shape with removable plates permitting servicing of elements without dismantling.

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Eclipse Pioneer Div. of Bendix Aviation Corp. Magnet metal laminations	Teterboro, N. J.
Swank, Inc.—Non-ferrous parts	Attleboro, Mass.
Sonotone Corp. Radio tube components of stainless steel	Elmsford, N. Y.
Benrus Watch Co.—Stainless steel watch parts	Waterbury, Conn.
H. E. Morse Co.—Special alloy heat treating	Detroit, Mich.

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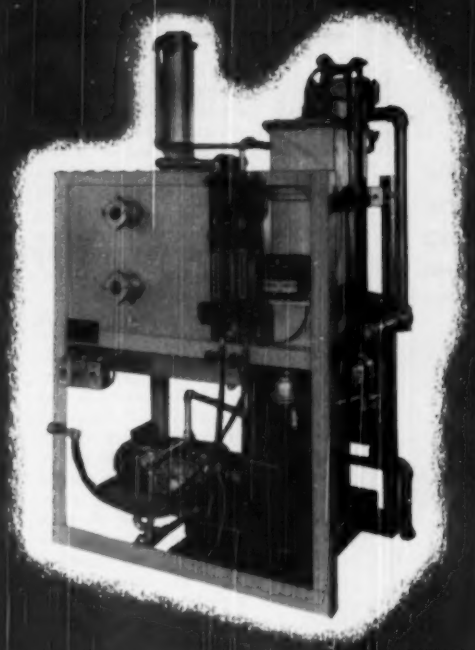

TYPE IG (1801)

THIS newest IG Type Combusted Gas Generator is expressly designed to supply furnace atmosphere for the decarb-free treatment of the most difficult high speed steels such as moly and 18-4-1 . . . and also gives the highest quality results on tools and dies of high carbon high chrome steels. It is an external type generator, using compressed air and natural, city or propane gas, delivering resultant atmosphere under positive pressure. May be used to supply: a pair of Hayes LR preheat and HGhigh speed furnaces; one or more carbon tool steel furnaces; or one or more high speed steel furnaces. The same unit is used successfully to provide protective atmosphere and a carrier gas for carbo-nitriding mild steel and sintered, powdered metal parts in production furnaces. The atmosphere provides accurate maintenance of carbon and clean surfaces in sintering and hardening carbon and alloy steel powders. Carbon steel parts are copper brazed in this atmosphere for protection against decarb and to maintain clean surfaces. Critical gold alloys and other non-ferrous metals are bright annealed with absolute minimum color changes.

- Capacities, 350 to 2000 CFH.
- Improved design of catalyst chamber.
- Closer control of chamber temperature.
- More complete control of gas-air ratio and subsequent atmosphere analysis.
- Rectangular design replaces cylindrical.
- High CO-low CO_2 atmosphere with low, controlled dew point.
- Easily varied, accurately controlled "Carbon Pressure."

REPRESENTATIVE IG USERS

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Bethlehem Steel Co.	Sparrow Point, Md.
British Pens Limited	Birmingham, England
E. M. Dart	Providence, R. I.
Detroit Steel Treating	Detroit, Michigan
Eastern Div.—Central Screw Co.	Keene, N. H.
Evans Case Company	N. Attleboro, Mass.
Gleason Works	Rochester, N. Y.
Gorham Mfg. Co.	Providence, R. I.
M. Joseph Sewing Machine Co.	Boston, Mass.
Kwikset Lock Co.	Anaheim, California
Lamson & Sessions	Birmingham, Ala.
Massachusetts Steel Treating	Worcester, Mass.
Merriman Brothers	Boston, Mass.
Metro Heat Treat Corp.	New York City
Motch & Merryweather Inc.	Cleveland, Ohio
Mueller Brass Company	Port Huron, Mich.
Powder Metal Products, Inc.	St. Marys, Penna.
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Scott & Williams	Laconia, N. H.
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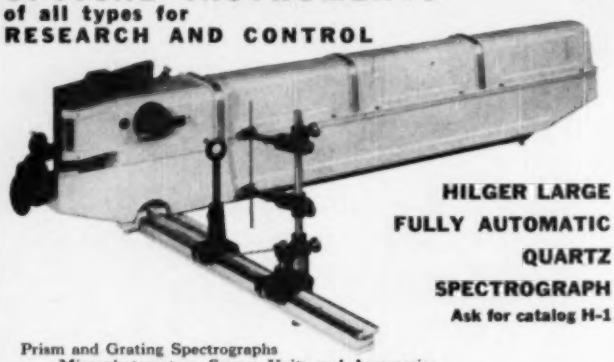

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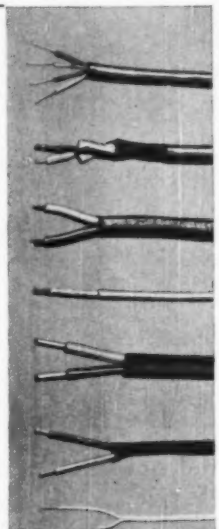

Thermo Electric CO. INC. FAIR LAWN NEW JERSEY

Ultramicroscopy

(Starts on p. 580)

or grain boundaries is a prominent example. Negative results achieved by the electron microscope in measuring the thickness of a slip band indicate that it is not of the order of several hundred atoms thick, as assumed previously by some theoreticians. Such negative evidence favors the modern theory of only several atoms thickness; slip bands appear surprisingly sharp at the highest obtainable magnifications. Strain bands — areas of disorientation in heavily cold worked metal — have apparently received little attention, yet the assumed "minimum" fragment size produced by cold work should be readily visible (700 to 10,000Å).

The electron microscope should give some evidence as to the accuracy of several divergent theories of nucleation prior to recrystallization, even though the smallest nuclei will not be detectable at formation; however, they may certainly be observed in an early stage of development.

Formulas for Strength — Already some formulas relating structure to strength have been tested. Four different theories have been advanced, each depending on a "characteristic dimension" of a crystalline particle. Experimentally, three medium carbon steels were quenched and tempered to diamond pyramid hardnesses of 720, 420 and 200. These presumably covered the range of precipitation for the type of steel used. Electron micrographs were then prepared in which the particle size and distance between particles appeared on the same scale. This required magnifications of 20,000, 4000 and 1000 diameters, respectively, giving a structure ratio of 5:25:100. Yield strengths (estimated from hardness) are 290,000, 180,000 and 75,000 psi., which are in the ratio of 400:250:100. Obviously, these observations do not support those theories that show an inverse proportionality of strength to scale of structure. However, if Gensamer's assumption (that the average distance between cementite particles on random directions through the specimen bears a logarithmic relation to the strength) is used to calculate the yield strength of the hardest speci-

(Continued on p. 588)

the "QUALITY" machine for materials testing

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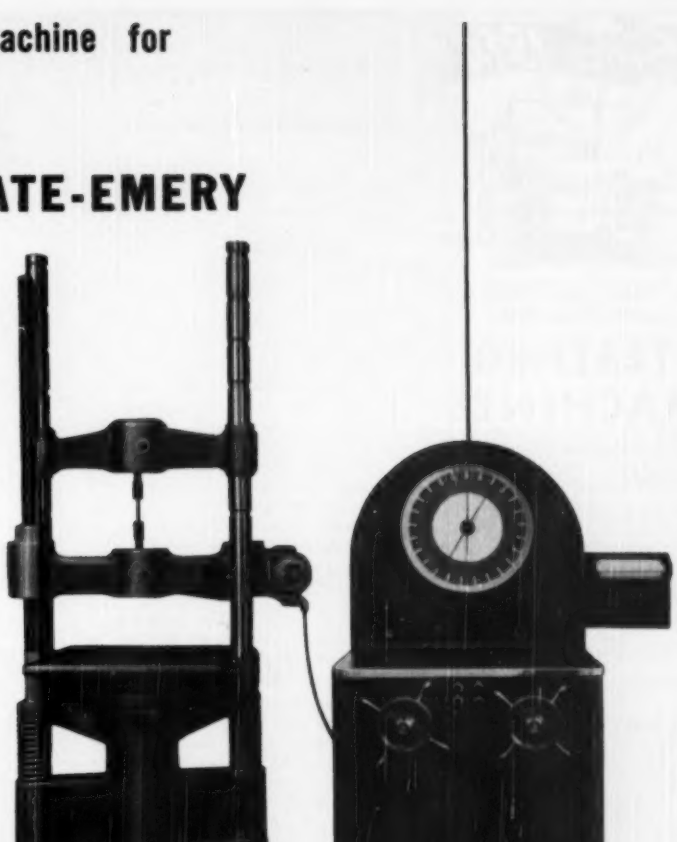

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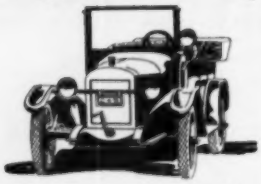

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Ultramicroscopy

(Starts on p. 580)

men from the other two, the result is 310,000 psi., or a figure as good as the one estimated from hardness. Orowan's formula,

$$Y = 2G\frac{a}{d},$$

where Y is the yield point, G is the shear modulus, a the lattice parameter and d the mean separation of particles, gives 335,000 psi. for the hardest steel (a reasonable check), but 16,000 psi. for the softest.

In Mott and Nabarro's theory, the greatest hardening of an alloy by a precipitate occurs when the distance between the particles of precipitate d is given by

$$d = \frac{Ga}{\sigma_1}$$

where G is the shear modulus, a the lattice parameter, and σ_1 is the internal stress around the precipitate and is equal to the yield point of the alloy. The average distance between particles calculated from this formula is 300Å for the hardest alloy, whereas measurement gives a range of 500 to 1000Å.

The experimental work outlined above is of interest from the point of view of the *method* rather than of numerical results (extrapolations), since one must consider that the image of a single ferrite grain may be 270 sq.ft. when magnified 20,000 dia.! Scanning large areas of several specimens would be a very lengthy task if the electron microscope were used with present-day replica techniques.

Precautions—The well-known precautions include avoiding any strain in the replica during stripping, the frequent necessity of etching away the entire sample to free the oxide or collodion replica, and detection of artifacts. Many artifacts are obvious—such as etching products adhering to the film; some are unexplainable and may lead to the necessity of a comprehensive analysis of the entire art of etching. For example, pure aluminum etched once with aqua regia yields a block-like structure, whereas the same material etched twice with aqua regia appears nodular! A much different appearance results after attack by aqueous hydrochloric acid than the one resulting

(Continued on p. 590)

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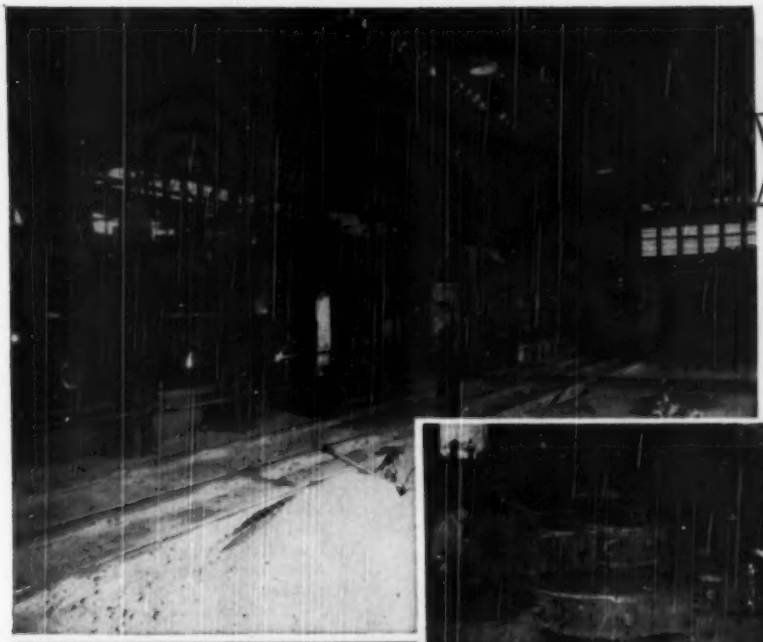

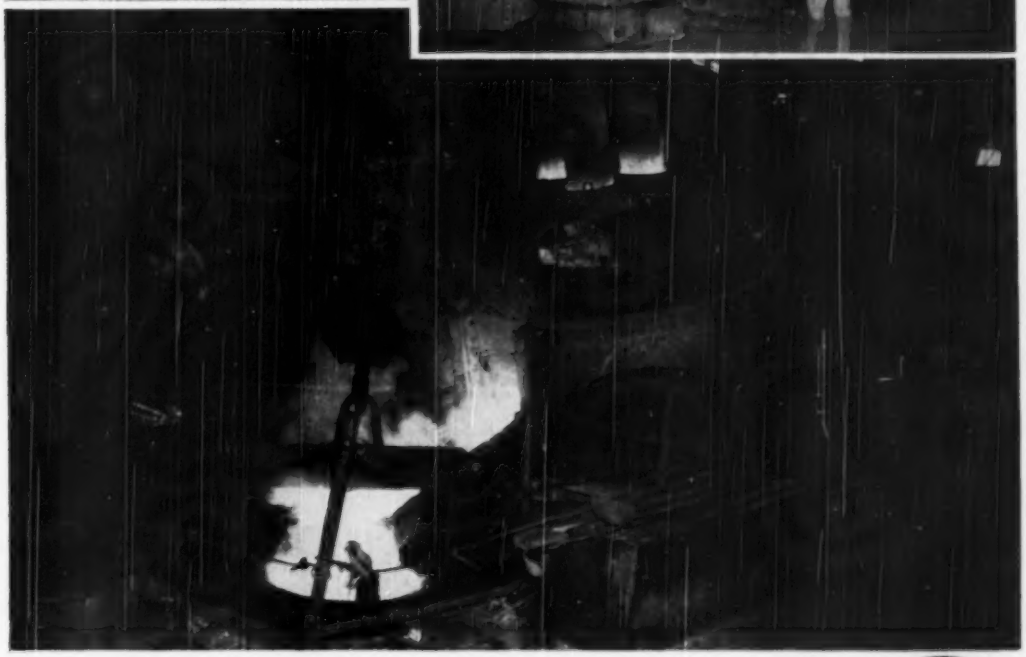

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Write for Descriptive Bulletins. Illinois Testing Laboratories, Room 523, 420 N. LaSalle St., Chicago 10, Ill.

PRECISION INSTRUMENTS FOR EVERY INDUSTRY

Ultramicroscopy

(Starts on p. 580)

from an etch by dry hydrochloric acid gas at 200° C. The cube-shaped relief from the former is believed to be representative of a surface oxide of the NaCl lattice type, whereas the dry HCl etch produces octahedra combined with cubes (possibly a direct reaction with the aluminum crystals).

Industrial applications cited include German investigations on hardening of duralumin and aluminum-magnesium alloys; studies of unalloyed steels and copper-beryllium alloy; investigations of brittle fractures in steel; comparison of cadmium crystals grown from a melt versus those grown from a vapor phase; investigation of surface films and metal oxide smokes.

Work of an exploratory nature has been done at the British Iron and Steel Research Assoc. on the temper-brittle alloy steels, and the brittle fracture of ferrite in iron, mild steel, and 4% silicon steel.

Microstructure of a water quenched carburized iron was studied in some detail at the National Physical Laboratory (Great Britain). Carbon ranged from 0.15% to 0.90%. The low-carbon area contained isolated carbide particles; a mottled appearance of the ferrite suggested incipient precipitation. The section with 0.40% C, quenched from 1750° F., revealed martensite, troostite, acicular and ragged ferrite. Pearlite transformation appeared as a fine dispersion of carbide in ferrite (rather than the dark "troostite" observed with the light microscope). The structure resulting from quenching from 1275° F. and aging seven weeks was also described; incipient precipitation was in evidence in the 0.7% carbon steel.

In work on aluminum and its alloys, the size of precipitate particles for a number of commercial aluminum alloys aged at varying temperatures has been determined. Elementary slip in aluminum has also been studied in some detail. Clusters of slip lamellae are resolved. Temperature does not alter the width of the lamellae or amount of slip, but the different grouping of the lamellae into clusters is affected.

J. J. Pierce

INDEX SECTION

METALS ENGINEERING LITERATURE

METAL PROGRESS

October 1950

Published by the

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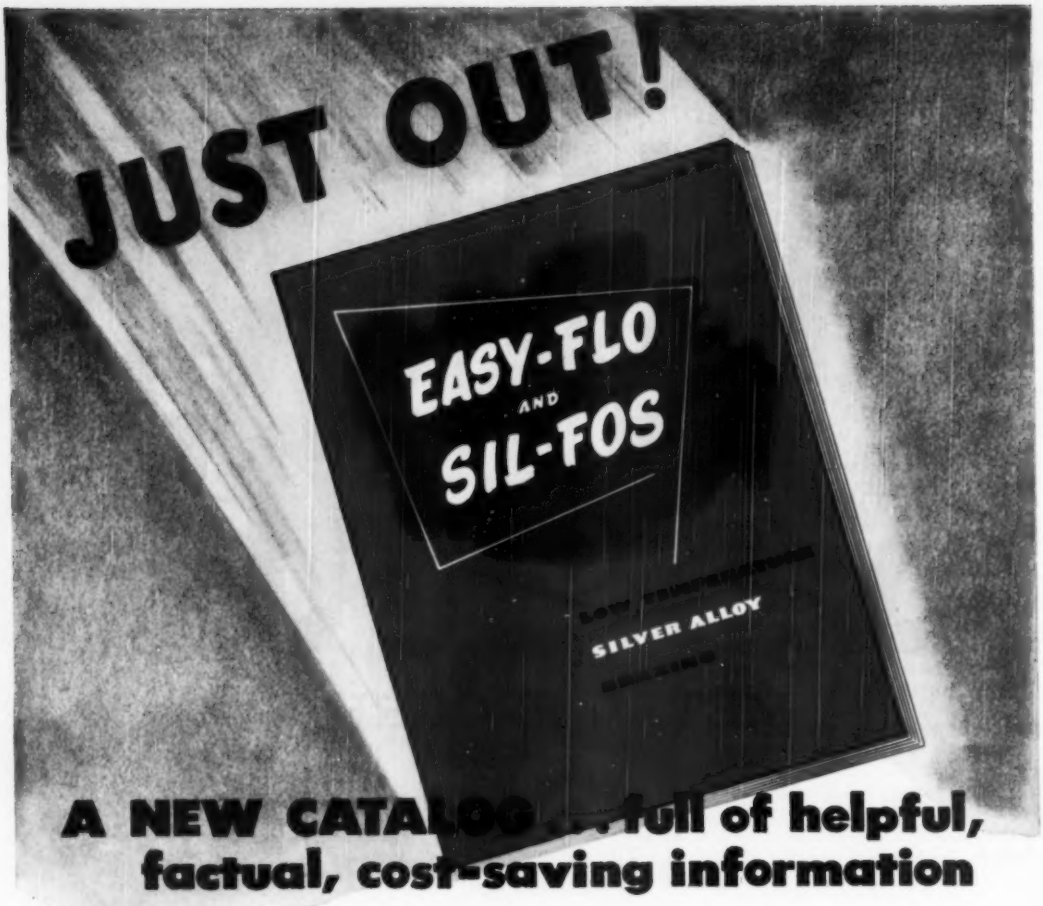

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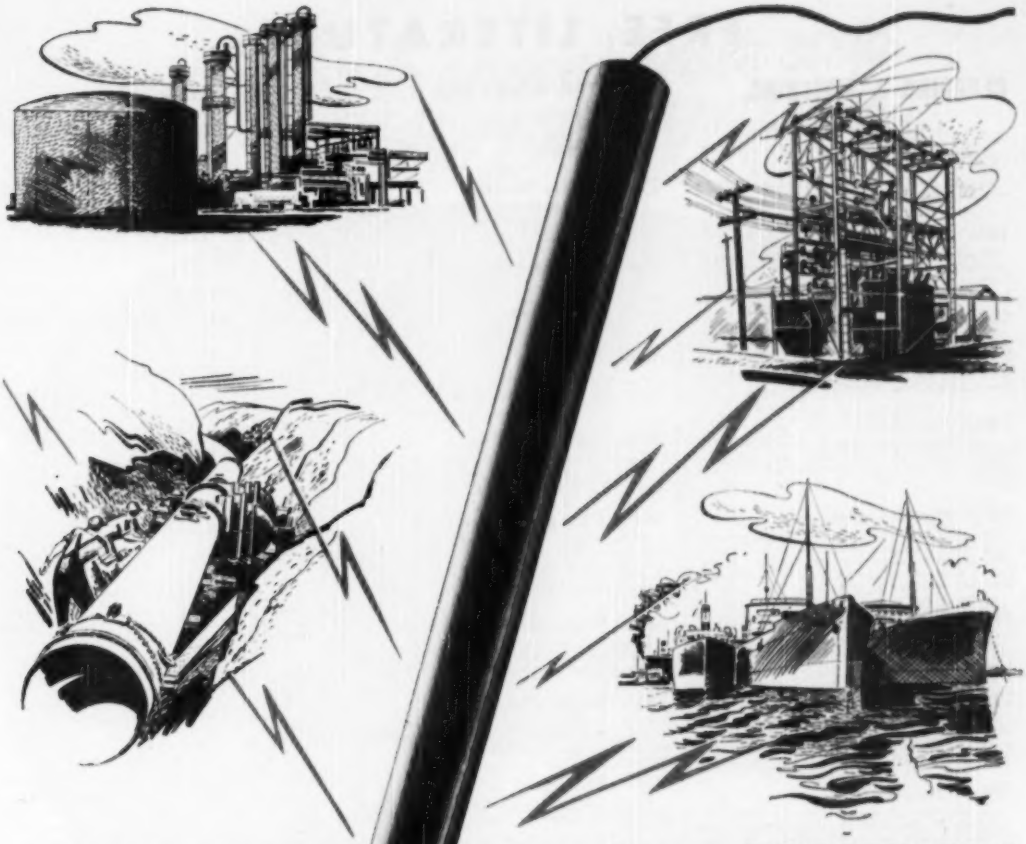

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FREE LITERATURE

CLEANING & FINISHING

783. Abrasives

18-page booklet discusses precision tumbling with Alundum abrasives. *Norton Co.*

784. Grinding Wheels

66-page booklet presents graphic and tabular information on selection of grinding wheels. *Norton Co.*

785. Metal Cleaner

Information on all drawing and cleaning problems, using Fluid-Film U-19 and Metal Cleaner No. 78 for rapid and economical cleaning of metal parts prior to plating, bonderizing, painting or vitreous enameling. *Northwest Chemical Co.*

786. Finishes

New "Black Book" gives full details on Black Magic finishes for steel, iron, zinc, cadmium, copper and its alloys. *Mitchell-Bradford Chemical Co.*

787. Metal Finishing

Complete set of data sheets on compounds and equipment for metal finishing, including the metex zinc stripper, cleaners for die castings, buffed copper, steel, and pressure spray washing machine cleaners. *MacDermid, Inc.*

788. Rust Preventives

Leaflet describes Kelcote rust preventives to protect stock in production, transit or warehouse. *J. W. Kelley Co.*

789. Plating

4-page leaflet describes Perflow process for nickel plating; gives semi-bright luster, levels polishing marks, color buffs easily, reduces finishing costs. *Harshaw Chemical Co.*

790. Chemicals

Attractive 32-page booklet gives comprehensive alphabetical listing of all Harshaw chemicals with complete section on electroplating. *Harshaw Chemical Co.*

791. Metal Stripper

4-page technical data sheet describes new metal stripper N-165 for stripping nickel plate from copper and copper alloys without attack on the base alloy. *Enthone, Inc.*

792. Finishing

New "Grinding Wheel Manual" supplies latest information on high speed grinding with full color illustrations of all types of problems in metal finishing. *Electro Refractories & Alloys Corp.*

793. Descaling

Booklet entitled "duPont Sodium Hydride Descaling Process" discusses the process, how it works and where it is used, with diagrams and technical information. *E. I. duPont de Nemours & Co., Inc., Booth 1602.*

794. Rust Remover

New bulletin 909 describes new process for removing oil and grease and also Diversey Everite for all descaling and de-rusting operations. *Diversey Corp., Booth 619.*

795. Rust-Proofing Process

4-page foldet describing new rustproofing process, which provides heavy, zinc-phosphate coating of high corrosion resistance on iron and steel parts. This process, called "Perm-Cote", features balanced solution to reduce sludging, low-coating cost, and pleasing appearance. *Deltex Corp., Booth 2222.*

796. Metal Cleaner

New booklet "Buffing Compound Removal was a Tough Job" gives complete information on latest development in metal cleaning research. *Cowles Chemical Co.*

797. Zinc Bright Dip

Leaflet including a control graph describes Luster-On Utility-15, a new zinc bright dip, as economical, uniform, brilliant and corrosion-resistant. *Chemical Corp.*

798. Belts, Metal

Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Bros. Co., Inc.*

799. Magnesium Anodes

Cathodic protection of underground and underwater structures against corrosion with magnesium anodes is discussed in convenient 12-page file folder. *Apex Smelting Co.*

800. Pickling

4-page leaflet describes Rodine, a control chemical or inhibitor for pickling baths. *American Chemical Paint Co.*

801. Rust Removal

4-page leaflet describes Deoxidine for removal of rust, and the cleaning and conditioning of metals for painting. *American Chemical Paint Co.*

802. Phosphate Coating

12-page leaflet describes phosphate coating chemicals and processes for paint-bonding, rust-proofing, protecting friction surfaces, improving drawing and extrusion. Separate chart lists products and applications. *American Chemical Paint Co.*

803. Protective Coatings

8-page bulletin gives a quick reference list of metal protective and paint bonding chemicals and processes of the *American Chemical Paint Co.*

804. Metal Cleaning

28-page booklet outlines important facts on selection of proper equipment for cleaning metal parts and products. *Alvey-Ferguson Co.*

805. Finishes

Full information and samples on Iridite Al-Coat finishes for aluminum surfaces. *Allied Research Products.*

806. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co., Booth 218.*

807. Blast Cleaning

There is a Pangborn rotoblast table, barrel, or table-room designed to bring you amazing savings. Write for bulletin 214. *Pangborn Corp., Booth 2560.*

808. Degreasing

28-page vapor degreasing manual describes process, gives advantages and basic design. Types of degreasers, operation and solvents are discussed. *Optimus Equipment Co., Booth 1732.*

809. Abrasives

108-page spiral-bound compilation of informative data provides a useful handbook on abrasives and grinding wheels. *Norton Co.*

HEAT TREATING

810. Heat Treating

Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Send for literature. *Barrett Div., Allied Chemical & Dye Works.*

811. Industrial Planning

New book 127 tells how you can share in a "round table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc., Booth 925.*

812. Furnaces

Information available on complete line of furnaces for every step from open hearth to heat treating line. *Loftus Engineering Corp.*

Furnaces • Induction Equipment

813. Furnaces

New literature describing high production dry cyaniding furnace CA 650. *Industrial Heating Equipment Co.*

814. Dry Cyaniding

Latest developments in the modern dry (gas) cyaniding process, with equipment and its applications, are presented in new 4-page bulletin. Both liquid quenching and slow cooling and their applications are described. *Surface Combustion Corp., Booth 1106.*

815. Atmosphere Furnace

4-page leaflet describes pit-type, controlled-atmosphere furnaces for gas carburizing, homogeneous carburizing, dry cyaniding, clean hardening and bright annealing. *Surface Combustion Corp., Booth 1106.*

816. Oven, Wide Range

Information is available on this new wide-range oven—300° to 2400° F. complete all-in-one furnace. *Sunbeam Stewart Industrial Furnace Div.*

817. Furnaces

Catalog A-17 illustrates and describes the line of Sentry electric furnaces for high quality hardening to produce maximum toughness and exceptional durability in high speed steel and high carbon, high chrome. *Sentry Co., Booth 602.*

818. Furnaces

Bulletin 424R lists many advantages of Rockwell retort furnaces for continuous automatic heat with accurate control of heat rate and product uniformity. *W. S. Rockwell Co., Booth 2701.*

819. Induction Heating

More economical production made possible through redesign of heat treating methods. Full details on application to individual plants furnished in booklet, "A Tocco Plant Survey — Your Profit Possibility for 1950". *Ohio Crankshaft Co., Booth 910.*

820. Furnaces

High temperature furnaces for temperatures up to 2000° F. are described in leaflet. *Carl-Mayer Corp.*

821. Ovens

12-page illustrated booklet describes complete line of heat treating ovens. Shows examples of standard and special designs comprising 3 major categories: batch, pit and continuous conveyor type. Using heat up to 1000° F., ovens are for use in heat treating steel, cast iron, aluminum, brass, bronze, magnesium. *Young Brothers Co.*

822. Furnaces

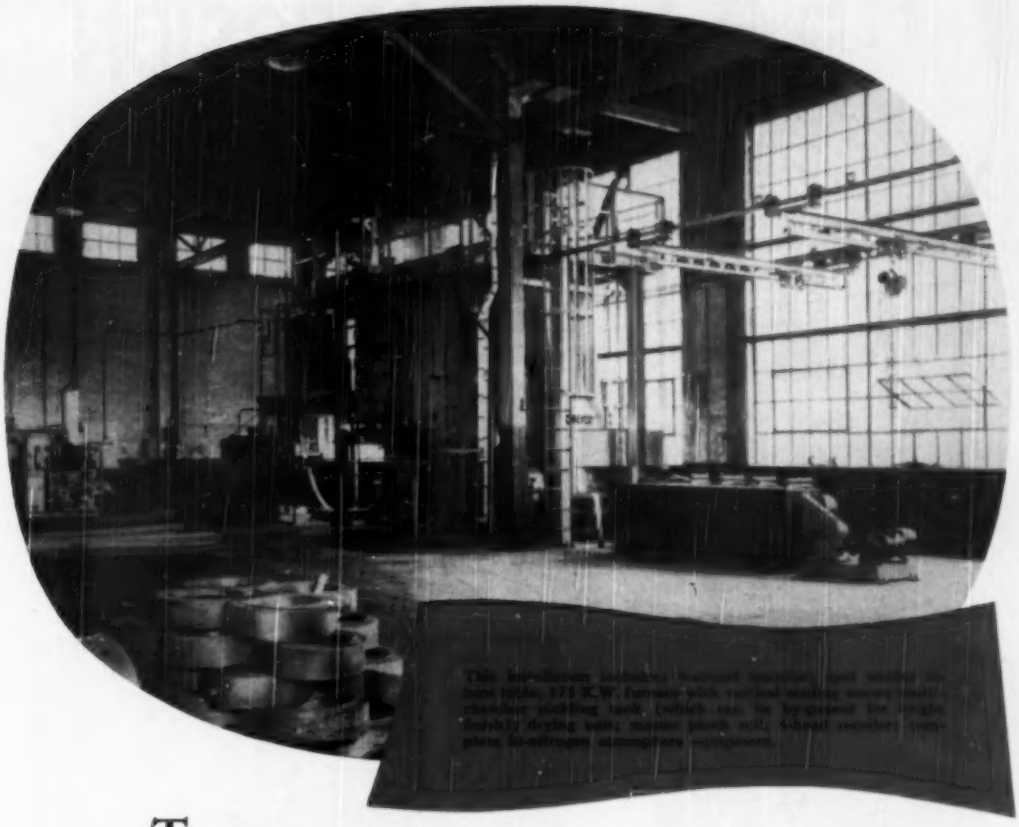
Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering, annealing and stress relieving, hot forming and light forging, shrink fitting and other induction heating applications. *Lindberg Engineering Co., Booth 1204.*

823. Furnaces

New 32-page fully illustrated catalog on Vapocarb-Hump furnaces. Describes the triple-control method of regulating atmosphere, and features improved control by use of fluid pump assembly. *Leeds & Northrup Co., Booth 1624.*

Continued on page 598

It costs less to anneal brass strip the DREVER way



TAKE a tip from leading producers if you want economical, high speed production of brass strip. . . Depend on Drever's controlled atmosphere continuous vertical strip annealing furnaces. Automatically, they provide close control over surface quality and metallurgical characteristics of clean, bright or matte finish brass, nickel-silver and many other types of non-ferrous as well as ferrous metals. Vertical design conserves floor space and lends itself to production line use. Installation pictured handles an average production of 2000# /hour in gauges from .008" to .060". Whatever *your* requirements, consult Drever on how to do it best at least cost.

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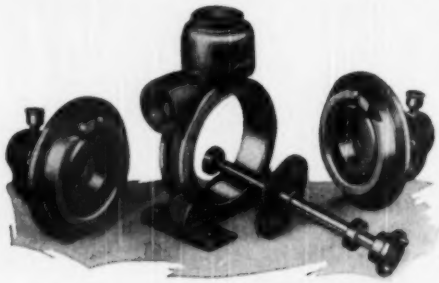
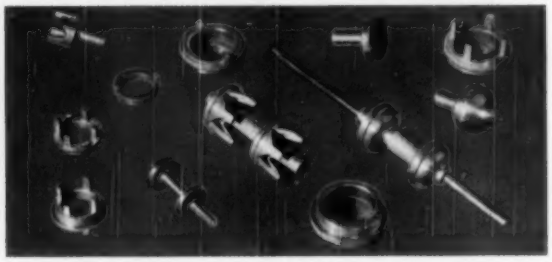
Fahralloy fixture for handling parts in heat-treating.



Fahralloy parts for pump handling hot, corrosive liquids.



Machined Fahralloy valve castings for an application involving abrasive wear and corrosion.

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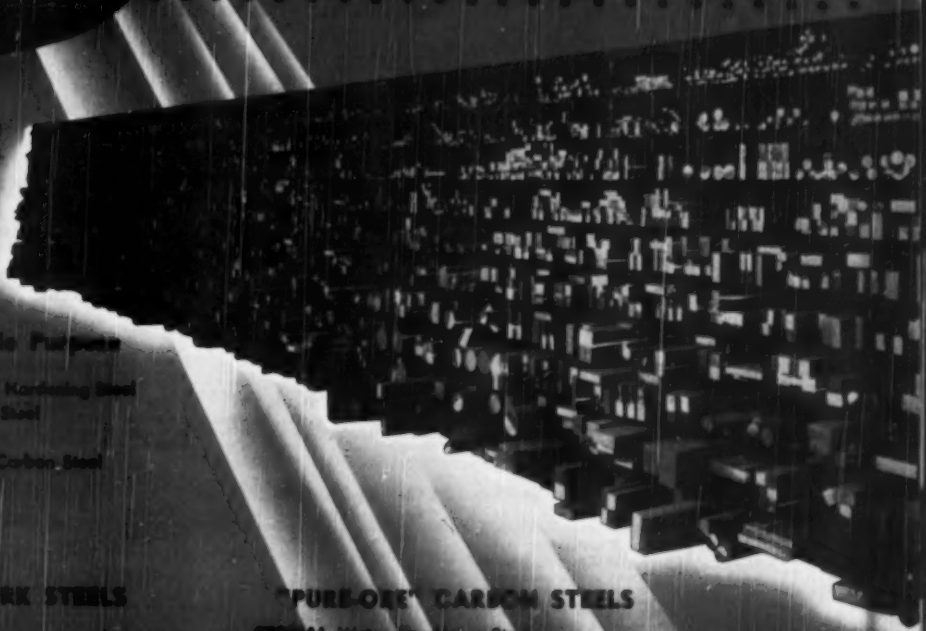

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FREE LITERATURE

Continued from page 594

824. Heat Treating

Leaflet describes Beacon heat treating salts for preheating, hardening, annealing, brazing and drawing. Non-burning carburizing compound and lead pot carbon presented. *J. W. Kelley Co.*

825. Quenching Oils

New line of Beacon quenching oils with "Quenzine" is described in comprehensive laboratory report bulletin. *J. W. Kelley Co.*

826. Heat Treating

Bulletin available on Series T Ipsen automatic heat treating unit for lower costs and efficient operation. *Ipsen Industries, Inc., Booth 715.*

827. Furnaces

New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co., Booth 1931.*

828. Furnaces

Catalog 110 features new heat treating furnaces and atmosphere charts. *C. I. Hayes, Inc., Booth 306.*

829. Furnaces

Send for full information on Rotary furnaces sized to suit individual production requirements, such as round or square bars to forging or rolling temperatures with billet weights up to 5000 lbs. *George J. Hagan Co.*

830. Furnaces

Booklet stresses the importance of efficient furnace combustion and describes how the CO_2 analyzer measures CO_2 content of flue gases to help air supply at optimum level. *Chas. Englehard, Inc.*

831. Industrial Furnaces

6-page folder describes 18 typical installations of gas fired, oil fired and electric furnaces of various types complete with specially designed mechanized equipment for bright annealing, scale-free hardening, carbon restoration, carburizing, and production heat treatment of products from small bolts to structural shapes 90' long. *Electric Furnace Co., Booth 1011.*

832. Industrial Furnaces

20-page booklet B-32 covers a very broad field of industrial furnaces, built and engineered to specifications and requirements of each heating application. *Drever Co.*

833. Furnace, Batch-Type

Booklet illustrates controlled atmosphere furnace in actual plant operation, includes charts showing uniformity of case depths and operating cost breakdowns. *Dow Furnace Co., Booth 2735.*

834. Furnaces, Gas Fired

Blue prints available for layouts of 20 mm. — 47 mm. — 40 mm. and larger shell cases, providing compact and efficient heat treating facilities with most economical investment. *Despatch Oven Co., Booth 2747.*

835. Furnace, Atmosphere

The tangential firing principle and simplified controlled atmosphere system of the Delaware Furnace is described and illustrated in new bulletin. Included is discussion of controlled atmosphere requirements for tool and die work. *Delaware Tool Steel Corp., Booth 2624.*

836. Flamatic Hardening

New 20-page catalog, "A Report to Industry on Flamatic Hardening Achievements", fully describes Flamatic Hardening Machine No. 2, and features 12 case history applications with operational photographs, part prints, and metallurgical specifications. *Flamatic Div., Cincinnati Milling Machine Co., Booth 2534.*

837. Furnaces, Reciprocating

Bulletin 815-AB completely describes versatile continuous reciprocating furnaces with positive atmosphere control for economical production heat treating. *American Gas Furnace Co., Booths 920-925.*

838. Furnaces

Catalog C-1304 illustrates and describes various types of batch and continuous heat treating furnaces. *American Gas Furnace Co., Booths 920-925.*

839. Furnaces, Rotary

Bulletins 801-804 and 1210-1212 illustrate and describe various continuous and batch rotary furnaces suitable for carburizing and other general and atmosphere heat treatment. *American Gas Furnace Co., Booths 920-925.*

840. Induction Heating

New bulletins on how to get better forgings at lower cost with Ajax-Northrup heaters that provide clean, quiet, concentrated heat treating, readily adaptable to automatic or conveyorized production. *Ajax Electrothermic Corp., Booth 1501.*

841. Furnaces, Salt Bath

4-page bulletin describes construction and operating characteristics of new salt bath furnace employing totally submerged electrodes. Well suited for heat treating in temperature range 1700° to 2400° F. *Ajax Electric Co., Inc., Booth 1501.*

Supplies

842. Quenching Oil

New technical bulletin describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co., Booth 1202.*

843. Carburizing

Graphs and charts show case depths and addition schedules in new bulletin describing deep case carburizing with Park-Kase No. 1. *Park Chemical Co., Booth 1202.*

844. Salt Baths

32-page bulletin entitled "Houghton Liquid Salt Baths" discusses the advantages of this process for tempering, brazing, annealing, hardening, reheating, and carburizing. Also contains many pages of factual heat treating data. *E. F. Houghton & Co., Booth 728.*

845. Heat Treating

Folder describes new improved Pentrate process for rapid, durable, economical black finishing for steel. *Heatbath Corp.*

846. Liquid Carburizing

Water soluble liquid carburizing with Park-Kase S-C is title of new bulletin giving complete operating instructions and methods of obtaining case depths up to .050". *Park Chemical Co., Booth 1202.*

847. Carburizing

Reduction in production time with Aerocarb D carburizing compound is discussed in technical data sheet. *American Cyanamid Co., Booth 1808.*

848. Salt Bath

Patented Neutra-Gas process for maintaining neutrality in salt baths in temperate range of 1500 to 2400° F. is described in new bulletin. *Park Chemical Co., Booth 1202.*

Parts • Containers

849. Heating Elements

4-page folder illustrates heavy cast metallic grid-type heating elements; shows methods of mounting elements on straight and circular walls; in roof; on hearths and car tops, etc. *Electric Furnace Co., Booth 1011.*

850. Parts, Baskets

Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts, and carburizing boxes are described in catalog 16. *Stanwood Corp.*

851. Alloys, Fabricated

Catalog available showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc., Booth 522.*

Equipment • Accessories

852. Dual-Fuel Burners

Send for detailed information on complete line of oil-gas burners including types for long flame, short flame, compressed air atomizing oil inserts and oil-to-gas converter for burning oil as a gas in existing gas burners. *North American Mfg. Co.*

853. Turbines

Bulletins available as follows: Data book 107, Gas Boosters 109, Four-Bearing 110, Blast Gates 122, Foundry 112, Descriptive bulletin 127 and Technical bulletin 126. Send for each by number for particular application. *Spencer Turbine Co. Booth 925.*

854. Cleaning Machine

Carbo-cleaner, the most compact, lowest priced carburizing-compound-cleaning machine on the market. Write for further details. *Thurner Engineering Co.*

855. Vacuum Metallurgy

Bulletin entitled "National Research Corp. and Vacuum Metallurgy" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and development facilities and services available to the metallurgist. *National Research Corp., Booth 1816.*

856. Gas Generator

Bulletin 1-11 describes how new inert gas generator Model 1 M1HE, rated at 1000 c.f.h., obtains the same analysis of inert gas, regardless of demand. Fully automatic, it gives accurate proportioning and assures precise analysis over full operating range. Ratio control adjusts for manufactured, natural, propane, butane or refinery gases. *C. M. Kemp Mfg. Co., Booth 920.*

857. Transformers

Tap changing transformers for furnace temperature control and general variable voltage use are illustrated in new bulletin. *Hevi Duty Electric Co., Booth 1931.*

858. Air-Gas Mixer

Bulletin L-600 describes the new McKee Consta-Mix proportioning valve for complete accuracy in a wide range of operations for industrial gas users. *Eclipse Fuel Engineering Co., Booth 920.*

859. Ammonia Dissociator

12-page leaflet describes this unit for the economical supply of pure hydrogen and nitrogen for use as a protective atmosphere. *Drever Co.*

860. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-coatings by High Vacuum". *Distillation Products, Inc., Booth 719.*

861. Heating Elements, Electric

Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

Continued on page 606

CONNECTING RODS:

Production: 400 per hr. (Capacity 600 per hr.) Tolerance: 2 oz. per rod. Stock: 1-1/2 x 12-3/4 in. r.c. squares. Equipment: One bank of four Ajax-Northrup induction heaters at 450 kw.

AXLE SPINDLES:

Production: 300 per hour per press. (Heater capacity 720 per hour.) Stock: 2-1/2-in. diam. by 3-15/16-in. billets. Equipment: Two 700 kva Ajax-Northrup induction heaters, capacity 720 billets per hour per heater.

TRANSMISSION SHAFTS:

Production: Output shafts (lower photo), 310 per hr. Stock: 1-3/4 in x 13 in. bars. Equipment: One bank of five Ajax-Northrup heaters at 400 kw. 1-3/32 in. x 12 in. bars for the main shafts (upper photo) are loaded three at a time, pyramid fashion, in the same heaters. Production is 190 per hour at reduced power.

TRANSMISSION GEARS:

Production: 235 per hr. Stock: 1-3/4 x 13 in. bars. Equipment: One bank of five Ajax-Northrup heaters at 400 kw.

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AJAX ENGINEERING CORPORATION

Better forgings

AT LOWER COST— WITH AJAX-NORTHRUP INDUCTION HEATING

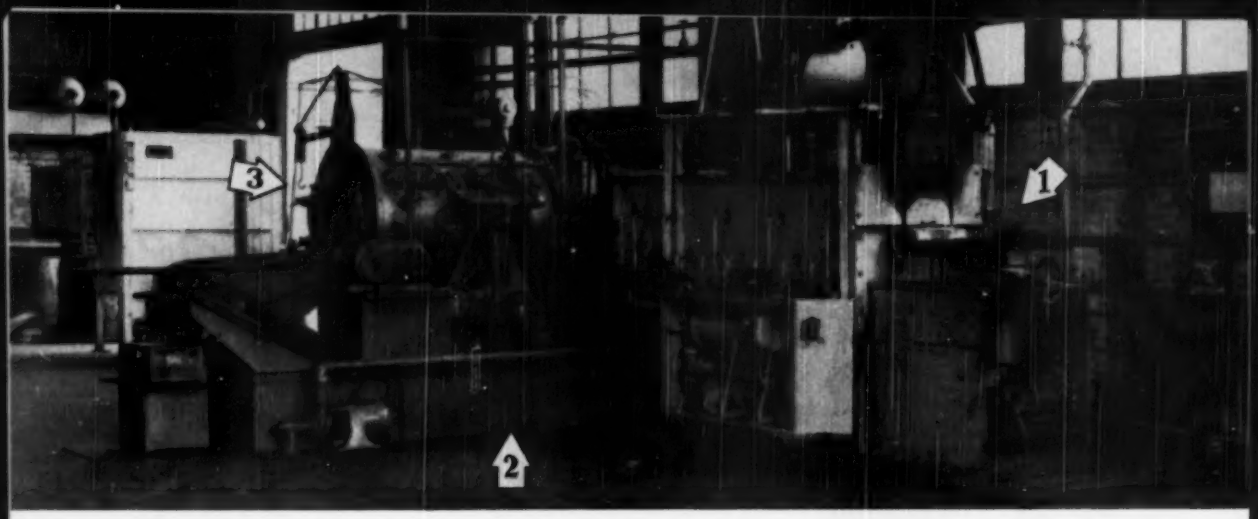
Produced by leading automobile manufacturers, these forgings have met the acid test of quantity production and cost analysis. Each one has proven cheaper to produce by induction heating.

Scale-free billets, fed directly from heater to press at exactly the right temperature *every* time, mean *better* forgings. Costs are lower, too, because there's no steel wasted in scale, die life is longer, and forging tolerances are closer to save machining. Steel savings alone . . . steel that would otherwise be lost in scale, in flash, and in extra machining operations . . . often are enough to pay for the equipment—and that's just one advantage.

Ajax-Northrup heaters are easy to live with . . . clean, quiet, do not over-heat the shop, because the heat is concentrated in the billet. They take a minimum of floor space, can be placed right in the production line, are readily adapted to automatic or conveyorized production.

Whether you're after better forgings, lower costs, or have a forging problem that can't be solved by ordinary heating methods, you'll find the answer in Ajax-Northrup. Send for our bulletins. Write and tell us your problems. Call on our 34 years of induction heating experience.

AJAX ELECTROTHERMIC CORPORATION
AJAX PARK • TRENTON 5, N. J.



A.G.F. FURNACES . . . Preferred by Commercial Heat Treaters

The typical installation of modern A.G.F. furnace equipment shown above is at the plant of the Mathews Heat Treating Company, Newark, New Jersey—one of the many commercial heat treaters who have found A.G.F. furnaces with positive atmosphere control to be the most versatile and economical for production heat treating.

A.G.F. furnaces with positive atmosphere control enable the commercial heat treater to handle the many varied jobs he receives on a production basis and to produce quality work at a lower cost per unit of work treated.

1. A.G.F. No. 166 Continuous Reciprocating, Full Muffle Furnace, capacity 150 to 300 pounds of work per hour, is suitable for all types of atmosphere work and general heat treating. Engineered to give maximum production per man-hour with a minimum of maintenance and work handling.
2. A.G.F. Automatic Quench Tank used in conjunction with the No. 166 Reciprocating Furnace assures better and more uniform hardening of the treated parts. Supplied for oil or water quenching. A variable speed drive is furnished for varying the quenching period.
3. A.G.F. No. 2 Batch Type Rotary Retort Furnace, capacity approximately 500 pounds of work per charge. This furnace handles a wide variety of work in independent batches. The time, temperature, etc., for each charge can be controlled to provide any desired treatment. The tilting feature reduces charging and discharging labor.

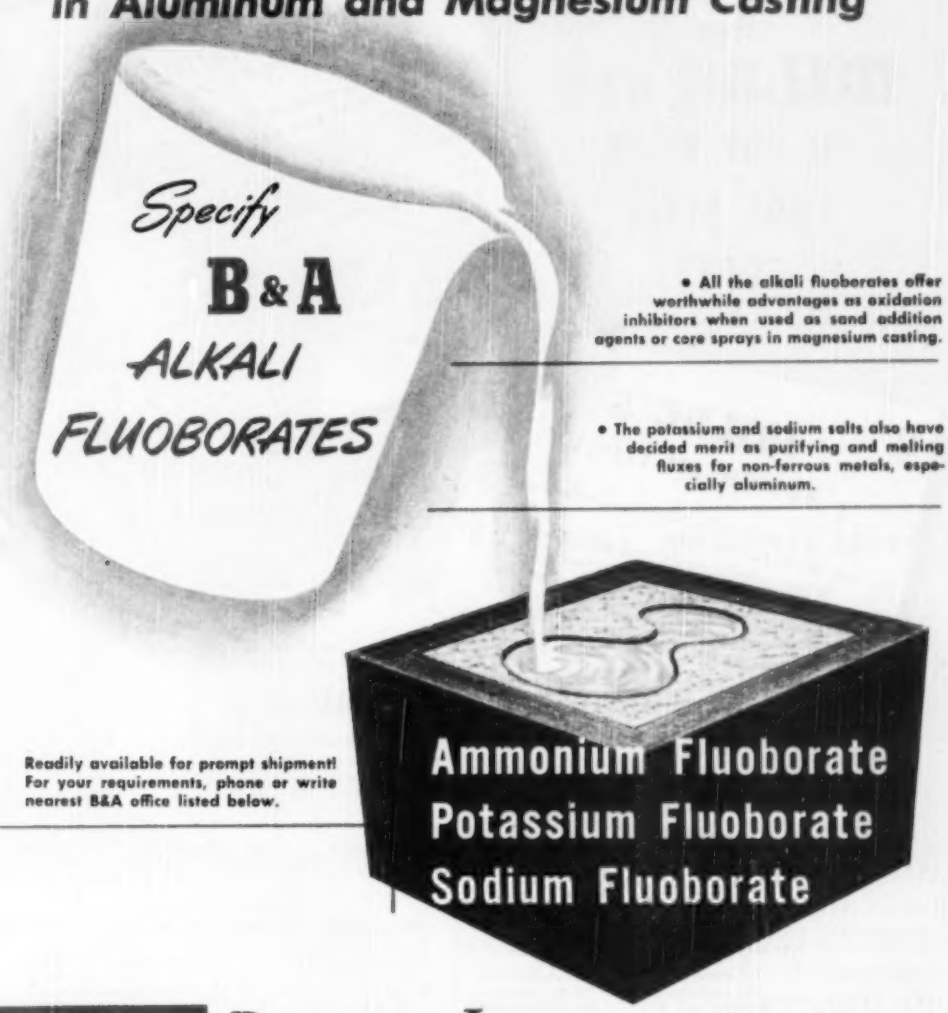
Visit the A.G.F. exhibit at the Metal Show,
Booth 1223.

AMERICAN GAS FURNACE CO.

1002 LAFAYETTE STREET • ELIZABETH 4, NEW JERSEY

To insure higher quality... fewer rejects

in Aluminum and Magnesium Casting



• All the alkali fluoborates offer worthwhile advantages as oxidation inhibitors when used as sand addition agents or core sprays in magnesium casting.

• The potassium and sodium salts also have decided merit as purifying and melting fluxes for non-ferrous metals, especially aluminum.

Readily available for prompt shipment! For your requirements, phone or write nearest B&A office listed below.

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In Canada: The Nichols Chemical Company, Limited • Montreal* • Toronto* • Vancouver*

SETTING THE PACE IN CHEMICAL PURITY SINCE 1882

* Complete stocks are carried here.

2 MILNE WAYS TO CUT YOUR TOOL STEEL COSTS

1

MILNE'S KOLORKOTE IDENTIFICATION

With Matching Heat Treat Card

Permanent, quick-as-a-glance identification of Milne tool steels is a sure thing because they are spray painted an identifying color over their entire length. With every shipment goes a heat treatment card of a color that matches the steel. You eliminate costly errors, delays, confusion and 'phone calls. Inventory control, scrap identification and stock movements are simplified.

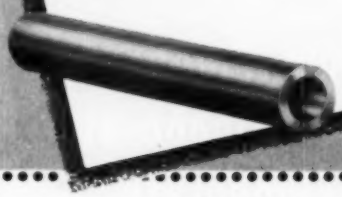
You know what you get...how to treat it... as long as you have it.

2

MILNE'S HOLLOW DIE STEELS

You get more tool per pound when you use Milne hollow steels.

Waste is minimized. Smooth finish inside and out saves hours of machining. Each piece is uniformly annealed *at the mill*. Prompt deliveries from stock. Eliminates waiting for forgings.



Visit us at Booth #2448 during the Metal Show in Chicago and get the complete story on

MILNE'S

New Pre-Shaped Steels

These are special cold drawn sections that start where machining often leaves off... make many machining operations obsolete.

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Established 1887

745 WASHINGTON ST., NEW YORK 14, N.Y.

America's Leading Tool Steel Specialists

Complete Line Of Tool Steels—Hollow and Solid

it's easy if you know how

As versatile as stainless is, you may find it difficult to appty stainless steel to your job unless you know which stainless analysis you need. That's why Crucible, pioneers in the development of this specialty steel, makes freely available to you an alert metallurgical staff. These engineers and metallurgists can show you which stainless analysis is best suited for your application. And how Crucible Stainless can be applied for maximum satisfaction.

Take full advantage of Crucible's half century of specialty steel leadership — leadership based on a keen devotion to detail . . . on every Industry-posed problem . . . whether the order is in tons or pounds. When you think of stainless . . . call in Crucible. CRUCIBLE STEEL COMPANY OF AMERICA, Chrysler Building, New York 17, N. Y.

CRUCIBLE first name in special purpose steels

STAINLESS STEELS

fifty years of Fine steelmaking

STAINLESS • HIGH SPEED • TOOL • ALLOY • MACHINERY • SPECIAL PURPOSE STEELS

All-Inconel radiant tube assemblies for use in pit-type carburizing furnaces. The radiant tubes were assembled by the Industrial Fabricating Company, Toledo, Ohio. The short-radius Inconel return bends were fabricated by the Commercial Metal Spinning Company, Toledo, Ohio.

Low Furnace Operating Costs with ALL-INCONEL Radiant Tube Assemblies

In practical terms, the use of all-Inconel® radiant tube assemblies means longer tube life, less down-time for repairs, and lower fuel bills.

Inconel resists corrosion, embrittlement, and destructive oxidation at temperatures up to 2000°F. Welded joints in Inconel have the same desirable characteristics as the alloy itself. These features mean long life and low maintenance for your Inconel radiant tubes. And you get lower fuel bills because the light walls possible with heat-resisting Inconel radiant tube assemblies give faster heating and require less fuel to bring your furnaces to working temperature.

One of the important factors leading to the availability of all-Inconel radiant tube assemblies is the development of the fabricated Inconel short radius return bend.

The Commercial Metal Spinning Company, Toledo Factories Building, Toledo, Ohio, supply them to the following specifications:

3½ in. O.D., on 5½ in. centers
4½ in. O.D., on 8 in. centers
5½ in. O.D., on 8 in. centers

The O.D. sizes shown can be obtained on other center-to-center dimensions on special order. Fittings for tube sizes other than shown are presently being developed.

Cold-drawn Inconel seamless tubing is produced in a wide variety of diameters and wall thicknesses to meet any requirements.

For specific information about Inconel radiant tube assemblies, write directly to Inco.

Remember, too . . . our Technical Service Department always welcomes an opportunity to help you solve high temperature and fabrication problems.

THE INTERNATIONAL NICKEL COMPANY, INC. • *67 Wall Street, New York 5, N. Y.*

EMBLEM OF SERVICE INCO TRADE MARK

INCONEL *. . . for long life at high temperatures*

...ations

...AL FINISHING...

METAL STRIPPER — A

An outstanding development for stripping defective electroplated nickel, copper, silver, cadmium and zinc from steel. Fast action . . . no basis metal attack. The highly polished grill cover illustrated has been completely stripped of nickelplate, and is ready for re-plating *without repolishing.*

EBONOL BLACKENING PROCESSES

Ebonol finishes are used to beautify a widely diversified list of superior quality products. Photo shows steel parts blackened with Ebonol-S and S-30; copper and brass with Ebonol-C; zinc with Ebonol-Z. U. S. Patents —2,364,993, 2,460,896, 2,460,898.

EMULSION CLEANER — 75

Oils, greases, buffing compounds, solid particles, deep seated in steel parts are cleaned out and completely removed by this emulsification process. Stubborn, gummy substances on die castings, milling machines, floors, motor blocks emulsify and disperse in water instantly.

ENAMEL STRIPPERS

Enthone has over 20 strippers for removing organic finishes — synthetic enamels, lacquers, vinyls, japans. The best strippers, tailor-made for your particular problem, are selected by laboratory technicians after test runs. This service is rendered free of charge.

...thone Incorporated

FREE LITERATURE

Continued from page 598

862. Atmosphere Generator

4-page leaflet describes the Nitroneal Generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co., Booth 2215.*

863. Gas Purification

8-page leaflet describes the Deoxo processes for the catalytic purification, hydrogenation and oxidation of gases. 4-page leaflet describes indicator for the detection and continuous measurement of traces of oxygen and hydrogen in gases. *Baker & Co., Booth 2215.*

864. Forges

Bulletin 300 illustrates and describes bench forges, regular and all-purpose forges, heavy-duty forges, Van Stoning forges, cutlery forges and rivet heaters. *American Gas Furnace Co., Booths 920-925.*

865. Tanks, Automatic Quenching

Bulletin 820 gives a detailed description with complete specifications on various size automatic quenching tanks for use with continuous heat treating equipment. Illustrations of typical installations. *American Gas Furnace Co., Booths 920-925.*

866. Immersion Heating

Bulletin IE-111 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co., Booth 920.*

JOINING

867. Brazing

Several illustrated case history applications show the speed and efficiency of brazing with Easy-Flo 45. *Handy & Harman Co., Booth 1600.*

868. Brazing

Reprints of 3-part article deals with practical and economical aspects of joining components of metal assemblies by furnace brazing; shows designs and methods of handling metal assemblies; how to select and apply brazing media and illustrates several types of continuous and batch-type furnaces used in copper and brass brazing steel assemblies and for brazing aluminum, etc. *Electric Furnace Co., Booth 1011.*

869. Metal Stitchers

Stitching with wire through metal is described in 8-page leaflet. Several applications are illustrated and equipment pictured. *Acme Steel Co., Booth 623.*

870. Fasteners

Complete file folder contains illustrations and engineering descriptions of fasteners and fittings for resistance welding, adjusting screws, adjustable feet and other products. *Ohio Nut & Bolt Co.*

871. Riveters

32-page illustrated booklet discusses "Hy-Power" hydraulics, and describes applications including portable, stationary and multiple riveters. *Hannifin Corp.*

LABORATORY • TESTING

872. Hardness Testers

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co., Booth 519.*

873. Tubes

4-page leaflet describes high temperature tubes for analysis by combustion, pyrometry and high temperature heat treatment. *Morganite, Inc., Booth 2737.*

874. Ductility

Operation and specifications of ductility testing machine which indicates drawing qualities of sheet metal are given in bulletin. *Steel City Testing Machines, Inc., Booth 2519.*

875. Metal Analyzers

Send for full information on Sargent-Slomin electrolytic analyzers for ferrous and non-ferrous metals and alloys, electroplating solutions, ores and minerals, micro and semi-micro specimens. *E. H. Sargent Co.*

876. Laboratory Equipment

Full details available on NSL Spec-Power, newly developed control cabinet featuring air interrupter for quick adjustment of voltage, a 5KVA AC spark providing increased stability and precision and redesigned unit for cutting down floor space. *National Spectrographic Labs., Inc., Booth 129.*

877. Testing Instruments

4-page leaflet illustrates and describes various types of testing machines; gives brief descriptions of Brinell, ductility, universal, transverse and special machines. *Steel City Testing Machines, Inc., Booth 2519.*

878. High-Temperature Testing

For precise hi-temperature testing send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

879. Refractories

New catalog entitled "Leco Zircon Refractory Ware" lists and describes zircon-base refractory products offered. *Laboratory Equipment Co.*

880. Microphotometer

Specifications for Jaco projection comparator microphotometer are given in this bulletin describing many advantages offered the spectrographer. *Jarrell-Ash Co., Booth 129.*

881. Synthetic Crystals

16-page leaflet describes synthetic optical crystals for instruments for infrared and ultra-violet spectroscopy, infrared photography and polarizing optics. *Harshaw Chemical Co.*

882. Furnaces, High Temperature

Fully descriptive brochures on research and production furnaces for annealing, brazing and routine heat treating problems. *Harper Electric Furnace Co., Booth 2554.*

883. Brinell

Bench model Brinell hardness tester (Model J) is illustrated and described in bulletin. *Steel City Testing Machines, Inc., Booth 2519.*

884. Photomicrographic Camera

12-page booklet on Gamma universal camera for use with reflected, transmitted or polarized light for micro, macro copying or enlarging work in the laboratory. *Gamma Instrument Co., Booth 418.*

885. Laboratory Apparatus

Leaflet describes testing and scientific equipment available for metallurgical laboratory. *Harshaw Chemical Co.*

886. Carbon Determination

6-page bulletin describes new induction carbon apparatus for faster carbon determinations. Discusses operation and cites typical results. *Fisher Scientific Co., Booth 2753.*

887. Spectrography

Bulletin describes spectrographic outfits for rapid, economical analysis, a scientific and well-illustrated presentation of prism spectrographs by a supplier of both prism and grating instruments. *Jarrell-Ash Co., Booth 129.*

888. Hardness Testing

Bulletin describes MH micro-hardness indenter, microscope attachment employing Vickers 136 deg. diamond pyramid point mounted in drum. *Erb & Gray.*

889. Mercury Cathode

Bulletin 220-I describes completely new magnetic mercury cathode Dyna-Cath and shows how it permits economical and high speed separation of iron in determination of aluminum in steel. *Eberbach & Son Co.*

890. Photography

Book entitled "Functional Photography in Industry" describes processes and techniques applicable to a wide range of endeavor. *Eastman Kodak Co., Booth 719.*

891. Testing Machine

4-page leaflet describes universal tester, precision instrument in seven different ranges for testing tensile strength of materials varying from only a few pounds up to 160,000 pounds psi. *W. C. Dillon & Co., Inc.*

892. Non-Destructive Testing

Bulletins available on two new testing instruments. Ultrasonic Metroscope for detection of internal defects and Automatic Cyclograph for production-line high speed rejection of parts off-standard in analysis. *J. W. Dice Co.*

893. Combustion Tubes

High temperature combustion tubes and boats are described in 4-page leaflet. *Burrell Corp.*

894. Finishing

New booklet, "Polishing Cloth and Abrasives", furnishes first-hand description and classification of some of the most used but least described accessories in modern sample preparation. *Buehler, Ltd., Booth 615.*

895. Laboratory Furnaces

Series of new bulletins available on all kinds of laboratory furnaces for atmosphere annealing, brazing, carbon and sulfur tests, hardness tests, salt baths and all other metallurgical experiments. *Boder Scientific Co.*

896. Microscopes

Catalog D-1010 illustrates and describes new E series of microscopes for the most exacting research work. *Bausch & Lomb Optical Co., Booth 502.*

897. Testing Equipment

Bulletin 261-A contains a long list of supplementary devices for adapting basic machines to widest possible variety of testing situations. *Baldwin Locomotive Works, Booth 407.*

898. Metallograph

12-page catalog describes this completely new all-in-one desk-type unit for metallographic work. *American Optical Co., Booth 618.*

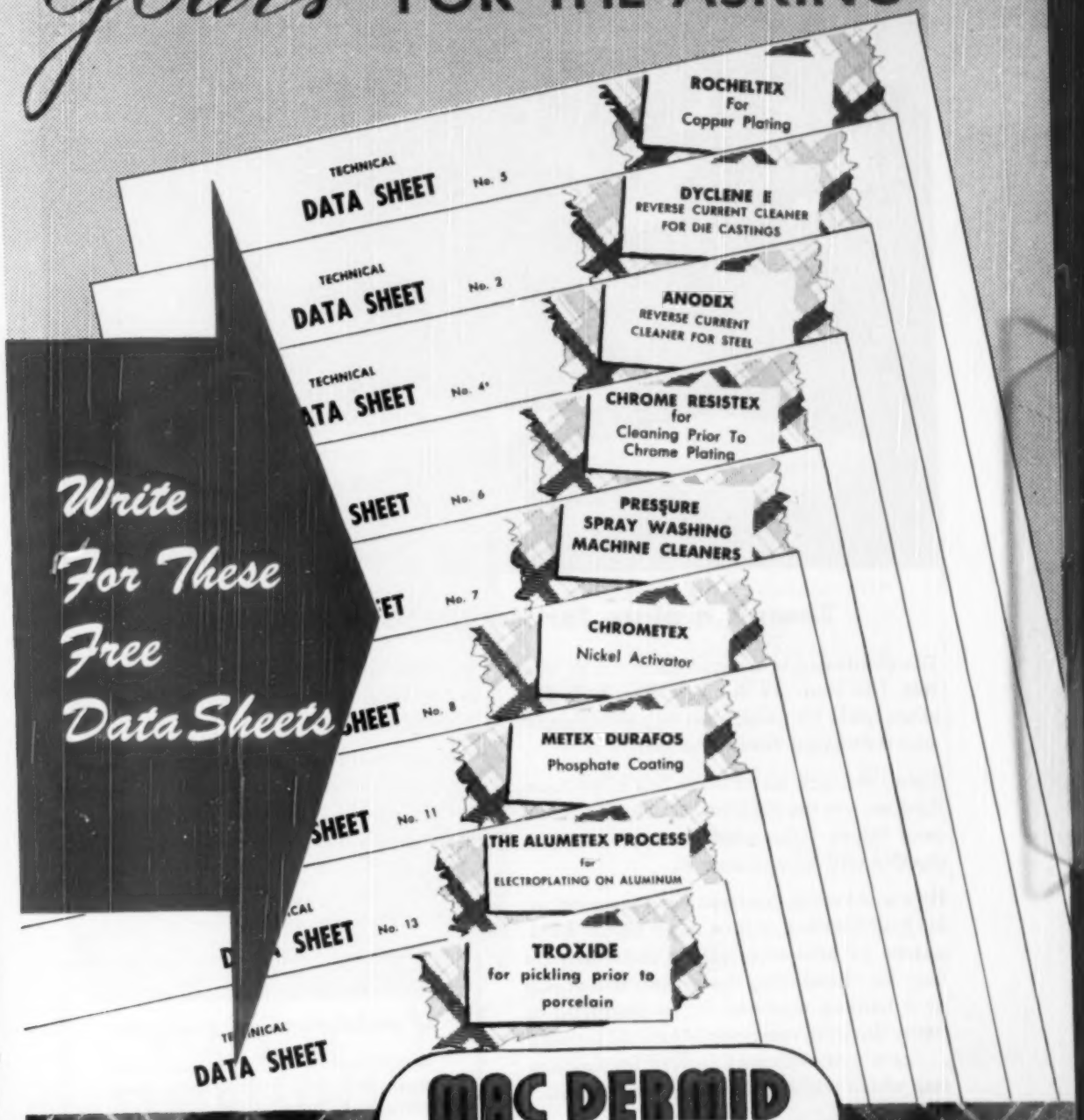
METAL FORMS

899. Alloys, Nickel

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hard-facing. Booklet, "Hastelloy High-Strength Nickel-Base Corrosion-Resistant Alloys", gives full details. *Haynes Stellite Co., Booth 901.*

Continued on page 614

Yours FOR THE ASKING



Write For These Free Data Sheets

MAC DERMID
Incorporated
WATERBURY 20. CONNECTICUT

There's a place for Houghton in this picture

The gentleman is in conference — with himself. The time, we hope, is after 5:30. The place could be the office of any metallurgist who is thinking through to 1951.

Going through his mind in this after-hours thinking are the problems facing him in the near future — the need for increased production and how to meet it.

He's wondering, perhaps, how to speed up his heat treating, or how to get higher hardnesses, or how to eliminate distortion. He may be considering the greater use of salt as a heating medium . . . or obtaining of better drawing compounds for cold forming . . . or a more efficient coolant for machining, which will enable faster production.

Houghton can be — should be — in the picture. This service organization of ours attained its growth through the years solely by rendering on-the-job aid to men like him. If the ideas are sound, our products naturally follow.

So when you're thinking ahead, put Houghton in the picture. Consider our 85 years of metal-working experience, our broad program of shirt-sleeved research, our personal plant help. When 1951 rolls around you'll be glad you did. E. F. Houghton & Co., Philadelphia and all principal cities.

The Houghton Line of metal-working products:

Heat Treating Salts, Carburizers, Quenching Oils, Cutting Oils, Rust Preventives, Cleaners, Drawing Compounds, Pickling Inhibitors, Lubricants.

Serving Industry Since 1865

2 NEW PRODUCTS for the Metal Industry

1 CONTROLLED OXIDATION PENTRATE*

for Blackening and Protecting

For the first time in the metal finishing industry . . . an easy-to-operate faster method with positive control which assures far better blackening and protective results than ever before believed possible.

The new C. O. Pentrate is equally effective in single or double baths and offers:

1. A bath whose blackening power is positively controlled to operate at continuous peak efficiency.
2. A two-component product — one consisting of a granular material which makes up the bulk of the bath and a second package containing easy-to-handle compressed briquettes for controlling the oxidation rate and maintaining bath strength.
3. The most economical product on the market today.

* Patent applied for

2 PENKAY CASE 2 and CASE 6†

for

Carburizing and Brightening

The newest development in activated liquid carburizing baths — a two-component method using easy-to-handle granular compounds and briquettes. It provides accurate control over carburizing rate and assures constant bath strength.

100% water soluble — provides extremely bright surfaces after quenching in either oil or water!

Case depths can be obtained which are equivalent to or better than those produced by ordinary insoluble and difficult-to-wash activated type baths.

Penkay contains a different activator never before used in carburizing baths and is responsible for carburizing rate stability and lustrous finish.

† Patent Pending

HEATBATH CORPORATION

SPRINGFIELD 1, MASS.

In Canada: Wm. Michaud Co., Ltd.
Montreal, Quebec

HEATBATH CORPORATION Springfield 1, Massachusetts

Please send me new data sheets on

☐ CONTROLLED OXIDATION PENTRATE ☐ PENKAY CASE 2 and CASE 6

NAME POSITION

FIRM ADDRESS

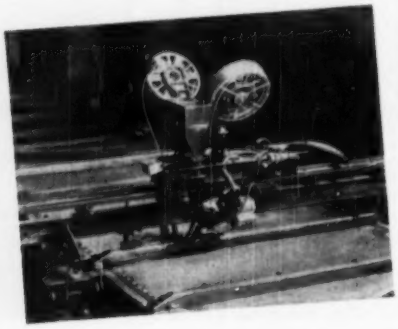
Fill in Coupon and mail today

Ideas on Welded Design—For the Engineer's Notebook

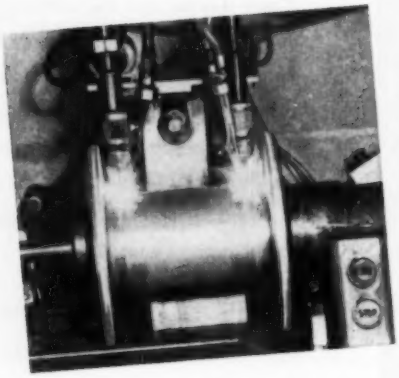
MAKE WELDS SIMULTANEOUSLY

When both ends or both sides of an object must be welded, both welds can often be made simultaneously. Production can thus be doubled — welding time cut in half!

Two UNIONMELT welding heads or two HELIARC torches can often be used — with the weldment turning or moving under stationary welding equipment, or with the welding units moving over the workpiece. Here are examples:



Two UNIONMELT welding heads are simultaneously welding both sides of a stake, joining it to the side panel of a railroad car. The bridge that supports the carriage can be easily shifted for welding both the stakes and diagonal side braces.



Fabrication of aluminum spools is speeded by use of two stationary HELIARC welding torches. The formed ends are joined to the barrel by girth butt welds. The pieces are held together over a backing mandrel, and turned under the HELIARC torches which make both welds simultaneously.

Better design for welding will help cut costs and increase production. For further information, call or write our nearest office.

Visit our booth (1001) at the National Metals Exposition, October 23-27, Chicago, and learn more about these processes. Plan to attend the American Welding Society's special session on "Design for Production Economies," October 24.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities

In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto

The terms "Heliarc" and "Unionmelt" are registered trade-marks of The Linde Air Products Company

NuTone, Inc., OF CINCINNATI, ONE OF THE WORLD'S LARGEST MANUFACTURERS OF DOOR CHIMES, SAYS:

This illustration of Anaconda Die Pressed Forgings is full size and has not been retouched.

"When we used brass sand castings for these parts, long and costly buffing was required. But these Die Pressed Brass Forgings changed all that. They are amazingly easy to machine ... and polish to a high gloss with a minimum of buffing".

You'll hear the same story wherever a comparison is made. That's because Anaconda Die Pressed Forgings are solid, dense-grained, twice-wrought metal—with double the strength of ordinary sand castings. Forged in dies, they have die-like dimensional accuracy, die-like surface texture that minimizes finishing costs. Publication B-9 goes into detail, telling how, when, why and where. Write for your copy today. Address, The American Brass Company, General Offices, Waterbury 20, Conn., in Canada, New Toronto, Ontario.

NuTone Solid Brass Door Knocker using the two Die Pressed Forgings illustrated above.

NuTone Electric Push Button using same face plate and requiring only a drilled hole in the cored boss and a brass-faced push button.

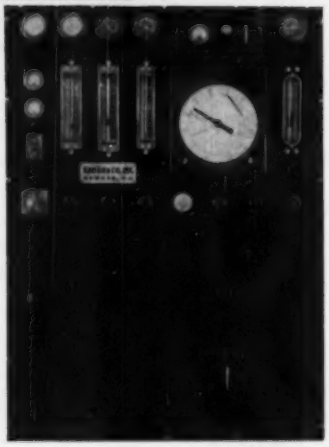
NuTone Mechanical Door Chime. Same face plate forging is used here, too. The pull and release knob is also a Die Pressed Forging with depressed lettering. Tone-bar and practically all other "behind the door" parts are made of Anaconda Brass.

ANACONDA®

DIE PRESSED FORGINGS

NITRONEAL ANNEALING *Gas* GENERATOR

Nitrogen-Hydrogen at lowest cost



Nitroneal Generator 500 CFH Capacity

Fundamentally new ammonia-air reactor produces pure Nitrogen with a controllable Hydrogen percentage (.1 to 35%).

You can obtain the ideal gas to fit your needs at will.

- **Fully Automatic**
- **No Operating Personnel Required**
- **No Explosion Hazard**
- **50% Less Costly Than Dissociated Ammonia**

Available in 100 CFH to 10,000 CFH Capacities

Catalog on Request

Baker & Co., Inc.

113 ASTOR ST., NEWARK 5, N. J.

DEOXO *Gas* PURIFIERS

GAS PURIFICATION AT REDUCED COST

Catalytic Operation At Low Pressure

At Room Temperature—

- **Removal of oxygen and/or hydrogen.**
- **Hydrogenation**

At 100° Centigrade—

- **Conversion of CO to CO_2**

At 200° Centigrade—

- **Methanation of CO to CH_4**

Reactions Complete — i.e. Less Than One Part Per Million Remaining.

No Maintenance—No Operating Cost—No Reactivation

Available in Capacities 200 CFH to 100,000 CFH

Deoxo Gas Purifier
Capacity 20,000 CFH

• Special Deoxo Units can be supplied to meet specific requirements as to pressure drop, operating pressure, physical size or capacity. Complete information on request.

Baker & Co., Inc.

113 ASTOR ST. • NEWARK 5, N. J.

AJAX ELECTRIC SALT BATH FURNACES

HULTGREN

offer proved advantages like these...

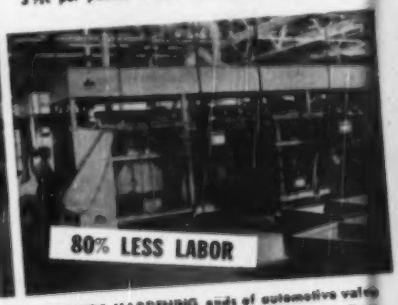
CARBURIZING automobile steering gears. .040 in. case in 2½ hours from 2 to 5 times faster than other carburizing methods.

PROCESS ANNEALING medium carbon alloy steel wire. 1200 pound charge annealed in 45 minutes compared with 12 hours previously required and in one-fourth the floor space.

NEUTRAL HARDENING silicon-manganese steel gears without decarburization. Direct savings 3½¢ per pound of work treated.

MARTEMPERING ball bearing races in mechanized unit eliminated 5 workers; reduced rejects from 12% to 0%. Distortion reduced from .003 in. to .001 in., eliminating need of die quenching.

HARDENING HIGH SPEED STEEL TOOLS. No decarburization or surface imperfections. Production increased 3 times over old method.



CYANIDE HARDENING ends of automotive valve pusher rods in 2 mechanized furnace lines reduced labor costs 80%.

Ajax Electric Salt Bath Furnaces are available in a complete range of sizes and types for:

CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING or HARDENING
STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
SOLUTION HEAT TREATMENT
DRAWING (TEMPERING)
DESCALING
CLEANING
DESANDING

...ON 4 HEAT TREATING APPLICATIONS OUT OF 5

Ajax Electric Salt Bath Furnaces offer tremendous advantages over conventional heat treating methods *in almost every case.* This fact is proved beyond question in well over 2,500 installations ranging from small batch type units to huge mechanized furnaces. And, by way of further proof, Ajax will gladly treat a job batch of your materials *under actual shop conditions* in the Ajax Metallurgical Laboratory. Thus you see exactly what results will be obtained, under what labor conditions and at what cost, before you buy.

Get your name on the list to receive TIPS AND TRENDS, the Ajax periodical that will keep you up to date on salt bath heat treating methods and developments. Each issue is chock-full of practical heat treating "know how" written by specialists. Available on request.

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AJAX ELECTRIC COMPANY, Inc., 910 Frankford Avenue, Philadelphia 23, Pa.

THE AJAX-HULTGREN PROCESS OF ELECTRIC HEAT TREATING FURNACES AND OUTFITS

In Canada: Canadi Ajax Electric Furnace Co., Ltd., Toronto, Ont.

Associates in Construction and Sales: Metallurgical Engineering Co., Ajax Electric Furnace Corp., Ajax Electrothermic Corp., Ajax Engineering Corp.

FREE LITERATURE

Continued from page 606

900. Metal Spinning

New Spincraft data book — a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

901. Alloys

New catalog "Electromet Ferro-Alloys and Metals" lists over 50 metals and alloys and describes unique technical service offered to the metal industries. *Electro Metallurgical Div., Booth 901.*

Castings

902. Steel, Alloy

New bulletin describes Evansteel, a chrome-nickel-molybdenum alloy designed for hard service. *Chicago Steel Foundry Co.*

903. Precision Castings

8-page, profusely-illustrated brochure describes Mircastings, with many application pictures and details. *Alloy Precision Castings Co.*

904. Castings, Steel

New bulletin describes Pyrasteel, the chromium-nickel-silicon alloy with prime qualities for resisting oxidation and corrosion up to 2000°F, and for withstanding most concentrated or dilute commercial acids and corrosive gases. *Chicago Steel Foundry Co., Booth 2003.*

905. Castings

"New Horizons" is title of attractive new booklet on precision castings. *Austenal Laboratories, Inc., Booth 121.*

906. Alloys, Nickel

Technical bulletin, "Cast 16% Cr - 35% Ni Alloys", completely illustrates heat, corrosion and abrasive-resistant cast alloys. *Electro Alloys Div., Booth 2024.*

907. Castings

Attractive 72-page brochure pictures facilities and scores of applications of castings, including aluminum, magnesium, bronze, permanent mold, electric alloy steel and semi-steel. *Howard Foundry Co., Booth 101.*

908. Castings

20-page booklet, "Misco Precision Castings", contains valuable technical information for manufacturers requiring small, accurate, alloy steel parts in quantity. *Michigan Steel Casting Co.*

909. Castings

Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

910. Alloy Castings

Complete story of how to solve corrosion problems with nickel chrome alloy castings is given in 24-page catalog. *Standard Alloy Co., Inc.*

911. Extruded Shapes

New booklets illustrate a wide variety of extruded shapes for industry, including rectangular and square in nickel silver and brass. *Titan Metal Mfg. Co.*

Forgings • Stampings • Parts

912. Heavy-Duty Forgings

16-page booklet on "Heavy-Duty Forgings" profusely illustrated, shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co., Booth 1911.*

913. Gear Size

24 pages of valuable engineering data present a standard procedure in determining the size and horsepower capacities of gears of different materials. *National Erie Corp.*

914. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co., Booth 416.*

915. Shapes

Precision shapes milled in long bars to close tolerances by a continuous milling process, from solid stock or from rolled, drawn or extruded shapes of any material described in 4-page leaflet. *Precision Shapes, Inc., Booth 2524.*

916. Forgings

New booklet "The Improvement of Metals by Forging" gives full details on forgings with controlled directional properties for durability, economy, strength and machinability. *Steel Improvement & Forge Co.*

917. Valves, Fittings

48-page catalog details stainless steel valve, fitting and accessory line, with engineering drawings, weights, dimensions, size ranges, materials, corrosion data, nomenclature and design information. *Cooper Alloy Foundry Co.*

918. Bimetal Elements

64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

919. Metalworking Data File

Fingertip reference file 502 contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

920. Contact Parts

Comprehensive, 36-page booklet discusses contact materials for the electrical industry. Silver, platinum, palladium alloys and tungsten are described. *Baker & Co., Booth 2215.*

Tubing

921. Alloy Tubing

New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co., Booth 1006.*

922. Tubing

For full information on solving your tubing problems and details on particular uses of seamless and weldrawn types, send for bulletin 31. *Superior Tube Co., Booth 2435.*

923. Steel Tubing

Informative literature on metal tubing. *C. A. Roberts Co., Booth 2435.*

924. Tubing

New data is incorporated in latest edition of reference handbook on methods of working seamless tubes and pipe of the intermediate B&W Croloys, ferritic air-hardening alloys containing ½ to 9% chromium. *Babcock & Wilcox Tube Co., Booth 2609.*

925. Seamless Tubing

"Mechanical Applications" gives complete information on how seamless tubing can be used to best advantage. *Peter A. Frasse & Co.*

METAL PRODUCTION

926. Grinding Mill Rolls

56-page booklet describes the grinding of hot and cold mill rolls. *Norton Co.*

927. Combustion Chambers, Graphite

M-9602 describes the graphite combustion chambers and "Karbate" impervious graphite burner nozzles. Outlines operation of the complete system and points out the principal features, such as long life, absence of corrosion, minimum maintenance, ability to withstand thermal shock, simplicity and moderate installed first cost. *National Carbon Co., Booth 901.*

928. Electrodes

Approximate carrying capacity of graphite electrodes is shown in this data sheet, which includes chart comparing carbon and graphite capacity. *International Graphite & Electrode Co.*

929. Machine Design

Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co., Booth 1724.*

930. Furnaces

Catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and elimination of skew shapes. *American Bridge Co.*

931. Melting, Induction

8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp., Booth 1501.*

METAL WORKING—GENERAL

932. Single Frame Hammers

16-page booklet illustrates single frame forging hammers, self-contained and standard types. *Erie Foundry Co.*

933. Press Forgng

Bulletin 75-B explains how many parts can be press forged better, faster and at less cost than by any other method. *Ajax Mfg. Co.*

934. Hydraulic Presses

16-page booklet illustrates presses for sheet metal forming and drawing, mechanical goods, extrusion and special purpose. *Erie Foundry Co.*

935. Hydraulic Presses

24-page illustrated booklet describes hydraulic presses in general, straightening presses, forcing presses, column-type presses; gives engineering data. *Hannifin Co.*

936. Double Frame Hammers

12-page booklet gives design and construction details of double frame steam hammers. *Erie Foundry Co.*

937. Safety Shoes

Illustrated booklet "Pioneering an Industry" describes popular styles for every foot hazard condition in plant operation. *Safety First Shoe Co., Booth 2520.*

938. Steam Drop Hammers

Profusely-illustrated 24-page brochure describes construction of steam drop hammers. *Erie Foundry Co.*

939. Greases

40-page book graphically and colorfully describes the fundamentals of lubricating greases and their application. *Shell Oil Co., Booth 315.*

940. Trimming Presses

Specifications and illustrations of many trimming presses are shown in 16-page booklet. *Erie Foundry Co.*

Continued on page 618

SEE SILVALOY WORKING EXHIBIT — BOOTH 1902 32nd NATIONAL METAL SHOW · INTERNATIONAL AMPHITHEATRE · CHICAGO OCT. 23-27!

SILVALOY

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To speed production, improve results or lower costs, Silvaloy rings, forms and shapes for "preplaced brazing" may be an excellent answer to your problems.

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There are no finer silver brazing alloys than the Silvaloy line . . . manufactured by the world's largest refiners of precious metals. Silvaloy Silver Brazing Alloys and APW Fluxes are standard for brazing quality. They are being used with outstanding success by many thousands of manufacturers throughout the world. Complete stocks are maintained by our distributors at all times for "fast delivery." Call them for prompt, intelligent service.

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APW

231 NEW JERSEY RAILROAD AVENUE, NEWARK 5, NEW JERSEY

NEW Aircomatic® Process jumps Welding Speeds to NEW HIGHS

SAVES 16 MAN-HOURS WELDING TIME . . . Dempster Brothers, Incorporated of Knoxville, Tenn., makers of the nationally-known "Dempster-Dumpster" found Aircomatic welding cut their aluminum container manufacturing costs.

The other method was slow — cumbersome, and ran the cost exceedingly high. With Aircomatic the same container was produced — at a welding cost reduction of approximately 16 man-hours.

Aircomatic is a new metal arc welding process that permits high-speed welding of aluminum, of aluminum bronze and of stainless steel — *in all positions*.

The process uses a bare wire electrode in coil form, continuously fed to the work within an inert gas shield. High current densities are used providing excellent penetration and high deposition rates, *permitting welding at speeds greater than ever before possible.*

Aircomatic welding has proved most economical . . . for its high deposition rate, in addition to permitting high travel speed, also makes possible fewer passes on heavy material, and faster, heavier deposits for overlay or build-up work. This means more weld per unit of arc time, whatever the job. Further, since the wire is bare and continuously fed through a shield of inert gas, electrode changes and slag removal interruptions are eliminated, thus permitting almost 100% arc time in using the high operating speeds.

Another important feature of Aircomatic welding is its minimization of distortion. This is due to its high speed operation (heat can be concentrated and moved rapidly along the work), plus the fact that a small amount of weld metal is all that's required in most joints.

The case studies on the opposite page show how this dramatic new welding process is helping others. While the facts and figures are startling, they could very easily be applied in your own shop . . . but find out for sure. Write . . . or phone your nearby Airco office. Ask for a copy of ADR 66: "Aircomatic Welding Process".

SAVES 4½ HOURS... Martin-Quaid Co., of Philadelphia, Pa., used the New Aircomatic Process to reduce the time and cost of welding huge stainless steel cylinders used in the manufacture of carpets. They found this revolutionary process cut materials cost 25% . . . and saved 4½ hours working time over the old method – and, at the same time, greatly increased the quality of the finished product.

REDUCES TIME ⅘'s . . . Consolidated Welding and Engineering Company, of Chicago, Ill., adopted the new Aircomatic process for welding aluminum separators. Immediately, major production and cost problems were solved: To weld one complete separator assembly took only 90 man hours – about 1/5 the time of other methods.

Further, Aircomatic's high current density and the attendant high welding speed confined the heating effects to the narrow weld-zone . . . completely eliminating distortion.

ELIMINATES LEAKS . . . Griffin & Company, of Louisville, Ky., found Aircomatic's high speed and the ability to make welds without interruption ideally suited to the fabrication of tanks for all-aluminum evaporative coolers. Production time and cost was cut to the minimum, and warpage and distortion were completely eliminated. Thus far, the company has made hundreds of these tanks without a single leak.

BOOSTS PRODUCTION 71% . . . The Stewart-Warner Corporation, South Wind Division, Indianapolis, Ind., join the upper and lower halves of its "Safe-Air Gas Home Heater" with the completely new, high-speed Aircomatic Process. This time-saving, cost-cutting process skyrocketed production 71% . . . and cut manufacturing costs in proportion.

See Aircomatic in Operation at our Booth—No. 422 Chicago National Metal Show October 23-27, 1950.

AIRCO **AIR REDUCTION**

Offices in Principal Cities

HEADQUARTERS FOR OXYGEN, ACETYLENE AND OTHER GASES . . . CALCIUM CARBIDE . . . GAS CUTTING MACHINES . . . GAS WELDING AND CUTTING APPARATUS, AND SUPPLIES . . . ARC WELDERS, ELECTRODES AND ACCESSORIES

FREE LITERATURE

Continued from page 614

941. Powder Metal Presses

Informative literature on powder metal presses. *Arthur Colson Co.*

942. Pneumatic Hammers

Economy, convenience and safety of pneumatic hammers are described in 8-page leaflet. *Erie Foundry Co.*

Machining • Cutting

943. Cutting Oils

Write today for the pamphlet, "New Improved Gulf L.S. Cutting Base", which describes how production can be speeded up with lower costs and better finishes by using this newly developed cutting oil. *Gulf Oil Corp.*

944. Cutting Oils

Data sheet describes Kelkut No. 20 E. P. soluble oil, giving characteristics when used with 20 parts or 30 parts water, for cutting and rust preventive jobs. *J. W. Kelley Co.*

945. Electron Drill

Illustrated folder gives full details on M10 electron drill with motor-driven automatic feed designed for production cutting of hardened metals of all types. *Elox Corp. of Michigan, Booth 2407.*

946. Oils, Cutting

Interesting facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids". *Cities Service Oil Co., Booth 1903.*

947. Saws

Catalog 49 describes complete line of metal-cutting saws, covering 35 models in 10 basic types, and including the world's fastest automatic production saw, the largest hydraulic hack saws, and some of the most widely used small shop saws. *Armstrong-Blum Mfg. Co.*

948. Lubrication of Hot Metals

New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

949. Vacuum Pumps

Bulletin V-45 describes complete range of high-vacuum pumps for insuring positive lubrication and long equipment life. *Kinney Mfg. Co.*

950. Cutting

4-page leaflet gives cutting data and full description of friction saw for high speed production cutting. *Kling Bros. Engineering Works.*

951. Sawing

Bulletin 2-MP illustrates the circular sawing of metals, and new automatic triple-chip method for sawing stock up to 6" accurately without burrs. Write for details on company letterhead. *Motch & Merryweather Co.*

952. Oils, Cutting

For the right combination to suit your specific requirements, write for the booklet, "Cutting Fluids for Better Machining". *D. A. Stuart Oil Co., Booth 328.*

953. Grinding Oil

Kelkut M 4 grinding oil (transparent) for internal, external, centerless and surface grinders is described in this data sheet. *J. W. Kelley Co.*

Tool Materials • Steels

954. Tool Steels

Full information on uses, compositions and heat treatment of carbon and carbon-vanadium tool steels. *Vanadium-Alloys Steel Co.*

955. Grinding Carbide Tools

142-page spiral-bound book discusses the grinding of carbide tools. *Norton Co.*

956. Tool Steel

Selector is handy chart featuring, general data and heat treating data on non-deforming, water hardening, shock-resistant, hot work, and high speed tool steels and hollow die steels. *A. Milne & Co., Booth 2448.*

957. Metal Cutting

New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co., Booth 1811.*

958. Tool Steels

Catalog available on finest pure-ore tool steels including tables and specifications for heat treating, forging, grinding and analysis of different types of steel. *Kloster Steel Corp.*

959. Tool Steels

Countless advantages of using J & L "E" steels for better tool production described in booklet, "Faster Machining, Smoother Finish, Longer Tool Life". *Jones & Laughlin Steel Corp.*

960. Tool Steels

To get the best results from your present equipment, send for the new 189-page Carpenter Tool and Die Steel Manual. *Carpenter Steel Co.*

961. Die Steel

Bulletin gives information on six types of tubular tool steels, including warehouse sizes. Gives heat treating information, physical properties, etc. *A. Milne & Co., Booth 2448.*

NONFERROUS METALS

962. Copper Sheets

New 23-page booklet, the product of a ten-year program of design developments and tests combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc., Booth 108.*

963. Alloys

New data sheet correlates ASTM, federal, army and navy specifications with 40 different Riverside alloys of phosphor bronze, nickel silver, beryllium copper and cupro nickel. *Riverside Metal Co., Booth 406.*

964. Alloy

For an alloy that is smooth-flowing under dies, requires a minimum of anneals and provides a beautiful finish, send for full details on Seymour Nickel Silver. *Seymour Mfg. Co.*

965. Beryllium Copper

Helpful engineering information contained in new series of Beryllium copper technical bulletins. *Beryllium Corp.*

966. Zinc, Coatings

16-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. *St. Joseph Lead Co.*

967. Copper Sheets

New 23-page booklet, the product of a ten-year program of design developments and tests combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc., Booth 108.*

968. Grinding Cutting Tools

30-page booklet describes the grinding of nonferrous cast alloy cutting tools. *Norton Co.*

969. Die Castings

Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*

970. Aluminum Alloy

Composition and properties of Z-50 aluminum alloy are given in 4-page file folder. *Apex Smelting Co.*

971. Machining

12-page bulletin covers the machining of Ampco Metal, with recommended practices for machining, grinding, honing, polishing, milling, broaching, sawing, drilling, reaming and tapping. *Ampco Metal, Inc.*

972. Zinc Coating

How Lithoform makes paint stick to galvanized iron and other zinc and cadmium surfaces is described in 4-page leaflet. *American Chemical Paint Co.*

973. Copper and Copper Alloys

40-page booklet presents review of the standard copper and copper alloys made by the American Brass Co. — their properties, range of application, and the forms in which they are manufactured. *Booth 2002.*

974. Aluminum Protection

Alodine, protective coating chemical for aluminum, bonds paint to aluminum and protects the metal economically, with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. 4-page leaflet describes Alodine and 5-page data sheet devoted to Brush Alodine. *American Chemical Paint Co.*

975. Copper Alloys

28-page booklet entitled "Copper and Copper Alloys Specifications Index". Section 1 lists most generally used alloys together with all applicable specifications. Section 2 lists specifications in numerical order with brief description of materials covered. *American Brass Co., Booth 2002.*

976. Aluminum

Copy of "Alcoa Aluminum Impact Extrusions" will be sent on letterhead request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

977. Die Casting Alloys

Properties of aluminum, magnesium and zinc die casting alloys offered by Apex Smelting Co. are charted in convenient 8-page file folder.

REFRACTORIES

978. Sillimanite

4-page illustrated bulletin discusses properties and applications of Sillimanite Hydrocast, a mullite base, castable refractory for use at temperatures up to 3000°. *Chas. Taylor Sons Co.*

979. Burner Blocks

8-page data sheet describes Alundum refractory burner blocks. *Norton Co.*

980. Refractories

Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

981. Refractories

New Insulation Chart IN-6D gives recommended insulation for every temperature range from minus 400° F. to plus 3000° F. *Johns-Manville Corp.*

Continued on page 622

Brass and Bronze Free Turning Rods

Furnished in all sizes from 1/64" for small diameter rods up to 10" for cast and turned rounds. Extruded shapes of various sizes also supplied.

Brass and Bronze Forging Rods

Standard large sizes of rounds are supplied up to 10" diameter; hexagons up to 4½" and squares up to 4¼" diameter (extruded and straightened).

Bronze Welding Rods

Seven different types meet all requirements. Titan's exclusive double deoxidation process assures ductile, high-strength, non-porous welds with the oxy-acetylene torch.

Extruded Brass Shapes

Squares, hexagons, half rounds, half ovals, and special shapes. Extruded and drawn rounds supplied up to 4½" and hexagons up to 3½"; extruded only shapes can be furnished up to 5½" max. diagonal.

Brass and Bronze Forgings

From ¼ oz. to 100 lbs. in weight. Produced to meet specified physical properties, corrosion resistance and finish.

Brass Pressure Die Castings

Parts having thin sections and intricate cored parts readily produced. Titan die castings have better finish, stronger structure, and greater accuracy than sand castings.

TITAN Brass and Bronze Products are supplied in analyses to meet every requirement. Write for descriptive catalogs on any of these products.

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"Quality Alloys by Brass Specialists"

NSL SPEC-POWER

Modernize your Spectrographic Laboratory

New methods and new applications require the latest in excitation units.

This new NSL SPEC-POWER features:

- Newly designed air interrupter which allows operator to adjust voltage of discharge with extreme precision during operation.
- A 5KVA AC Spark providing increased stability and precision.
- 30 Ampere DC Arc and Spark-ignited AC Arc.
- Redesigned cabinet for compactness in work area.

THE NSL SPEC-POWER offers you important improvements and refinements which give you greater production control and efficiency. It is streamlined to cut floor space to a minimum. These are just a few features that make NSL SPEC-POWER the finest of its kind.

We will be glad to supply full details and specifications about the NSL SPEC-POWER, perhaps arrange an opportunity for you to examine this new power unit and prove its amazing versatility.

NSL OFFERS
Complete Analytical Service
with complete facilities to analyze any type material or any size job. Write for details.

NATIONAL SPECTROGRAPHIC LABORATORIES, INC.

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Resists Oxidizing Sulphuric Acid Bath at 160 to 180 deg. F.

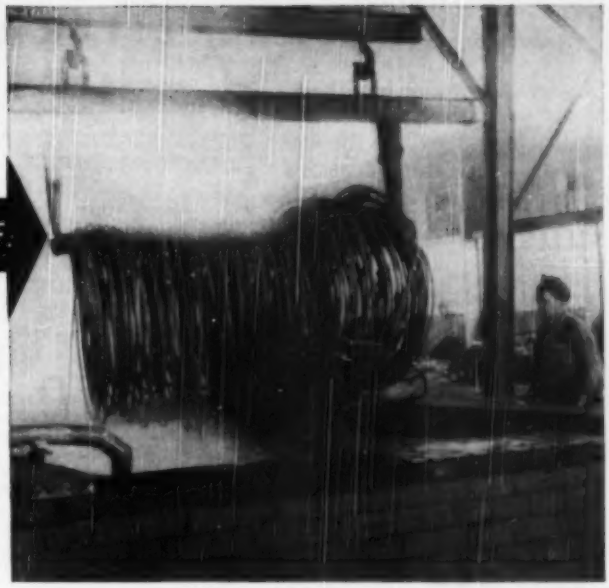
Corrosion rate in agitated solution less than 0.007 in. per year

This HASTELLOY alloy pickling assembly operates in a violently agitated, heated solution of sulphuric acid. The solution is oxidizing in nature at the liquid level, and strikes against the assembly at high velocities. In the face of these severe conditions, the corrosion rate of the assembly is only 0.002 to 0.007 in. per year.

HASTELLOY alloys were selected for this job because of their high strength, light weight, and ease of fabrication, as well as their superior corrosion resistance.

You will find that the fabrication of equipment from wrought or cast HASTELLOY alloy is an economical solution to many tough corrosion problems involved in modern steel processing. There are four grades of this versatile material of construction—each specially designed to resist certain common mineral acids and oxidizing agents, even at elevated temperatures. They can be readily fabricated by most common methods. Procedures are generally the same as those used to fabricate the austenitic stainless steels.

If you would like samples of HASTELLOY alloys to try out under your own operating conditions, fill out the handy coupon below. Descriptive literature and price lists are also available, without obligation.



The high strength of HASTELLOY alloys makes possible the lightweight construction of equipment from standard wrought forms. The hooks in this pickling assembly handle 3,000 lb. of coiled wire or bar stock, and they are made from much lighter gage sheet than would be required if steel had been used.

Here is the HASTELLOY alloy clad yoke bar and trunnion before assembly.

The I-section is joined to the hook with HASTELLOY alloy welding rod.

HAYNES Trade-Mark Alloys

Haynes Stellite Division
Union Carbide and Carbon Corporation
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USE THIS HANDY COUPON

Haynes Stellite Division, 725 So. Lindsay Street, Kokomo, Indiana
Please send me samples of HASTELLOY alloys A, B, C, and D for testing under actual operating conditions.

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COMPANY_____
ADDRESS_____

"Haynes" and "Hastelloy" are trade-marks of Union Carbide and Carbon Corporation.

FREE LITERATURE

Continued from page 618

982. Refractory Cements

16-page booklet describes line of refractory cements. *Norton Co.*

STEELS

983. Bars, Forging

There is a stainless steel "tailored" to fit your specifications for chemical and physical properties. Write for 112-page booklet of forging data, "Evaluating the Forgeability of Steels". *Timken Roller Bearing Co., Booth 1006.*

984. Steel, Cold Finished

16-page bulletin entitled "You Can Make Them Better with Cold Finished Jalcase" gives technical information, charts and graphs about Jalcase 10 and the other nine grades of Jalcase. *Jones & Laughlin Steel Corp.*

985. Nickel Alloys

Bulletin T-7 contains 24 pages of new data on high nickel alloy Inconel, with tables on compositions and properties as well as information on "Inconel X", one of the newer age-hardenable Inco nickel alloys. *International Nickel Co., Booths 1107 & 1120.*

986. Steel, Stainless

12-page booklet "Widest Range of Sizes, Highest Standard of Quality" illustrates modern production methods and discusses principal grades and uses of stainless steel. *Carnegie-Illinois Steel Corp.*

987. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

988. Steel

Informative literature on cold-drawn steel. *Bliss & Laughlin, Inc.*

989. Metal Plates

For full information on solid or clad plates in the exact grade you need to combat corrosion, oxidation and contamination, write for new A-L Plate Book. *Allegheny Ludlum Steel Corp.*

990. Alloys, Nickel

New technical bulletin T-6 discusses resistance of nickel and its alloys to corrosion by caustic alkalies. *International Nickel Co., Booths 1107 & 1120.*

Alloy Steels

991. Steels, Heat Treated

New bulletin gives engineering data on Rycrome and Nikrome "M", two high performance alloy steels supplied in the heat treated condition, ready for use in heavy-duty applications. *Joseph T. Ryerson & Son, Inc., Booth 1016.*

992. Strip Steels

New 32-page book catalogs 785 different sizes of Sandvik's cold rolled strip steels. Complete information on 133 cold rolled and unhardened sizes and 652 cold rolled hardened and tempered sizes. Gives thickness, width, hardness, type of edges and weight in pounds per 100 ft. Also useful conversion tables. *Sandvik Steel Co.*

993. Steels, Alloy

"Heat Treating Republic Alloy Steels", a 56-page illustrated booklet, provides an explanation of various heat-treating methods now generally used, and includes charts showing the mechanical properties obtainable in response to tempering at various temperature levels for 21 types of constructural alloy steels. Write for Adv. 540. *Republic Steel Corp.*

994. Steel, Alloy

New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc., Booth 1016.*

995. Speed Alloy

Bulletin 905 describes multiple benefits of this newest of speed steels in plates up to 72" wide and 6" thick. Provides easier machining, longer tool life, faster delivery, lower costs, and quality moldings with fewer rejects. *W. J. Holliday & Co.*

996. Alloys

Informative literature on iron powder. *Ekstrand & Thaland, Inc., Booth 423.*

Stainless Steels

997. Stainless Steels

Full information, including prices, is available on advantages of free-machining Enduro stainless steel. *Republic Steel Corp.*

998. Steel, Stainless

Attractive 30-page booklet on making the most of stainless steels in the textile industry. *Crucible Steel Co. of America.*

TEMPERATURE MEASUREMENT & CONTROL

999. Pyrometer

Compact indicating pyrometer, Model 192, for flush and surface mounting, is described in new bulletin. *Wheelco Instruments Co., Booth 1909.*

1000. Pyrometer

Catalog 1101-J describes how the new multiple-point Celectray controls up to six furnaces with the accuracy of a single-point instrument. *Weston Instrument Co.*

1001. Thermocouples

A new 34-page catalog, Reference H, will furnish complete data on thermocouples, quick-coupling connectors, thermocouple wire, lead wire, protection tubes, etc. *Thermo Electric Co.*

1002. Controller

Potentiotrol, a potentiometer controller, operating with the Wheelco "Electronic Link", is described in bulletin. *Wheelco Instruments Co., Booth 1909.*

1003. Potentiometer, Portable

Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

1004. Pyrometer

Catalog No. 80 illustrates and describes the Pyro Optical Pyrometer for quick, accurate temperature readings on minute spots, fast moving objects and small streams in a temperature range from 1400° F. to 7500° F. *The Pyrometer Instrument Co., Booth 302.*

1005. Cabinet Series

Line of instruments known as "Cabinet Series" designed to enable user to incorporate auxiliary equipment into the case of a direct-reading electronic controller is described in bulletin. *Wheelco Instruments Co., Booth 1909.*

1006. Control

SO_3 recording or controlling equipment, now being increasingly used in sulfur burning, ore roasting, SO_3 recovery, and magnesium heat treatment, is described in 4-page leaflet. *Leeds & Northrup Co., Booth 1624.*

1007. Temperature Testing

New bulletin 1724-D includes photos, complete description and prices of the Pyrolance for temperature readings of molten metal in nonferrous foundries. *Illinois Testing Labs., Inc., Booth 819.*

1008. Thermocouples

Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

1009. Tempilstiks°

"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Claud S. Gordon Co., Booth 925.*

1010. Heat Protection

4-page folder describes new Pyrotac, automatic protection against temperature damage. Giving safer operation of any heated equipment, this device utilizes proved "Alnor" pyrometer performance that assures safety. *Illinois Testing Labs., Inc., Booth 819.*

1011. Potentiometers

Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

1012. Control Devices

New 64-page catalog 8303 illustrates over 100 different industrial control devices for temperature, flow, pressure, liquid level and humidity. *Brown Instrument Div., Booth 1802.*

1013. Gauges

Bristol Co. has just issued a 32-page bulletin on its series 800 line of recording gauges. Information is given on pressure gauges for ranges from 0 to 2 inches of water to 0 to 10,000 pounds per square inch, vacuum gauges, low range draft and pressure gauges, barometers and absolute pressure gauges.

WELDING

1014. Welding Rods

24-page illustrated booklet describes welding rods and procedures, including tobin bronze, phosphor bronze, everdur, manganese bronze, copper, super-nickel and other alloys. *American Brass Co., Booth 2002.*

1015. Welding, Stainless Steel

Valuable information about welding of stainless steel with Airco stainless electrodes contained in new catalog ADC-650B. *Air Reduction Sales Co., Booth 422.*

1016. Welding

Information available on fast, clean, process for welding sheet steel with the Heliarc torch. *Linde Air Products Co., Booth 901.*

1017. Electrodes

New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low alloy, low hydrogen electrodes. It shows the importance and effectiveness of low hydrogen electrodes in welding low alloy, high tensile steels, mild steel under highly restrained conditions, and sulphur-bearing free machining steels. *Arcos Corp.*

1018. Brazing Alloys

Standard pricing schedule and torch brazing instructions for Silvaloy silver brazing alloys listed in 4-page leaflet. *American Platinum Works, Booth 1902.*

1019. Electrodes, Welding

New catalog presents complete line of shielded-arc electrodes for welding of mild steels and alloy steels; gives complete specifications, operating characteristics, mechanical properties, and applications. *McKay Co.*

1020. Weld Nuts

4-page leaflet illustrates and gives production sizes with weights of weld nuts for projection welding. *Ohio Nut & Bolt Co.*

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How NITROGEN Refines Grain Size...

Produces Harder, Stronger, Tougher Chromium Steels

When nitrogen is added to high-chromium steel, it greatly refines the grain size of the metal and materially increases its strength, toughness, hardness, and wear resistance—without sacrificing ductility or reducing corrosion resistance. For these reasons, nitrogen-bearing chromium steels are well suited for cutlery, turbine blades, and various machinery parts that are subject to extreme wear.

Added to Steel In Ferrochrome

Nitrogen is usually added to chromium steels in the form of nitrogen-bearing ferrochrome containing 0.75 per cent and up of nitrogen, 70 per cent chromium, and a maximum of 0.10 per cent carbon. Depending upon the chromium content of the steel, which can range between 12 and 30 per cent, the nitrogen content may vary between 0.06 and 0.20 per cent. The amount of nitrogen added to high-chromium steels should be 1 part of nitrogen to between 100 and 200 parts of chromium, depending upon the chromium content of the steel.

Nitrogen-bearing ferrochrome is added to the furnace in the same manner as ordinary ferrochrome. Nitrogen recovery will average about 90 per cent.

Improves Cutlery Steel

Cutlery steels and other martensitic stainless steels, such as the 12 to 14 per cent chromium low-carbon steels that are used for turbine blades, are hardenable by heat-treatment. Hardenability and strength increase with the carbon content. And, since nitrogen is a more powerful austenite-former than carbon, it is sometimes used as a substitute for part of the carbon, or as a supplement to the carbon, to increase the strength and hardenability of these steels.

Nitrogen has distinct advantages over carbon for this purpose because ductility, toughness, and corrosion resistance are retained when nitrogen is added to steel. It increases the hardness of cutlery steels without detrimentally affecting toughness or corrosion resistance. The effect of small additions of nitrogen in increasing the hardness of cutlery steels is shown in the table below.

Reduces Grain Growth During Hot-Working

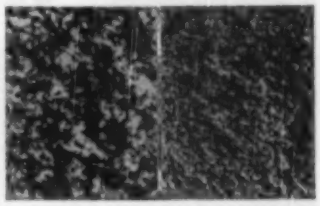
The ferritic high-chromium stainless steels to which nitrogen is added have a finer grain size than ferritic steels without nitrogen, which are comparatively coarse-grained. These include the 16 to 18 per cent chromium wrought steels, high-chromium steels containing small percentages of nickel, and both the cast and wrought 20 to 30 per cent chromium steels. The function of nitrogen when added to the ferritic high-chromium steels is to preserve a fine grain size.

The nitrogen-bearing, high-chromium wrought steels are more readily rolled and forged than comparable steels containing no nitrogen, because grain growth is inhibited during hot-working operations. Greater yields are therefore obtained in rolling and fabricating. Also, strength and toughness are increased as a result of the grain refinement caused by the nitrogen addition.

Effect of Nitrogen on the Hardness of Cutlery Steels*

% Cr	% C	% Si	% Mn	% Mo	% N	Rockwell C Hardness	Brinell Hardness Number (by conversion)
13.15	0.12	0.30	0.38	...	0.03	41	387
13.25	0.13	0.29	0.42	...	0.10	48	460
13.36	0.23	0.28	0.40	...	0.03	46	437
13.27	0.21	0.34	0.32	...	0.08	51	496
12.70	0.32	0.30	0.37	...	0.04	50	484
13.41	0.35	0.31	0.41	...	0.11	56	560
17.37	0.41	0.32	0.41	0.75	0.036	41	382
17.25	0.44	0.30	0.42	0.75	0.09	53	522
17.30	0.66	0.29	0.38	...	0.03	51	496
17.08	0.60	0.31	0.40	...	0.11	55	547
17.26	0.80	0.28	0.39	0.76	0.032	52	509
17.25	0.80	0.27	0.45	0.74	0.09	57	573

*Steels oil-quenched from 950°C. Held 5 hr. at 200°C. and air-cooled.



Note the extent to which nitrogen refines the grain size of these specimens containing about 27 per cent chromium and 0.35 per cent carbon. The specimen at the left contains 0.05 per cent nitrogen; the one at the right, 0.30 per cent nitrogen.

Greater Strength for Austenitic Steels

Small percentages of nitrogen will increase the yield point and tensile strength of the austenitic chromium-nickel steels. These include the well-known 18 per cent chromium, 8 per cent nickel steels, and also the 25 per cent chromium, 12 per cent nickel steels. The improvement in strength is gained at no sacrifice of workability. Furthermore, nitrogen promotes the formation of austenite.

Metallurgical Service Available

ELECTROMET nitrogen-bearing ferrochrome is furnished in the following standard analysis:

Chromium	67 to 71%
Carbon	0.10% max.
Silicon	0.30 to 1.00%
Nitrogen	0.75% approx., or higher if desired.

It is available for immediate shipment in lump sizes of 25 lb. by 8 mesh, or 15 lb. by 8 mesh; also, in a crushed size of 2 in. by down.

If you would like additional information about the production of nitrogen-bearing steels, ask to have one of our metallurgists call, or ask for the booklet, "Nitrogen In Chromium Alloy Steels." Write to the address given above or to the ELECTROMET office nearest to you. Offices are in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York and San Francisco. In Canada: Welland, Ontario.

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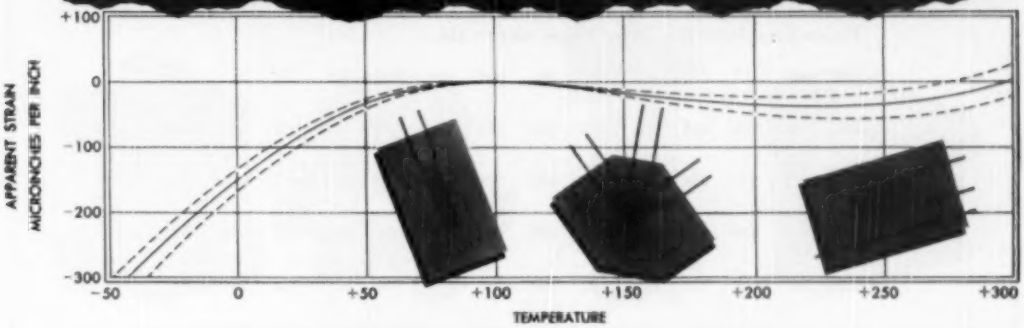

THE *NEW* BALDWIN SR-4®
SELF-COMPENSATING STRAIN GAGE

Further broadening the field of usefulness of Baldwin SR-4 Strain Gages, this newest addition to the line eliminates another unknown in stress-strain investigations by providing built-in compensation for rapid variations in temperature occurring during the test.

One obvious use is in aircraft testing, where rapid changes in plane elevation bring corresponding rapid changes in temperature. The effect is to introduce unknown errors in the strain gage readings even though conventional dummy gages are employed.

Previously, compensation for temperature changes invariably called for the use of a dummy gage. The new self-compensating gage makes this duplication unnecessary and minimizes errors that might be introduced by lead or lag in the dummy gage temperature change.

The new Self-Compensating gage will be manufactured in rosette, double-element, and single-element form. Temporarily, only the single-element will be carried in stock; others are available on special order.

Gage lengths available are 7/8"; 13/16"; 3/8"; and 1/4". Copper-nickel wire is utilized in the element. Degree of compensation is suggested by the chart above.

A data sheet giving detailed dimensions, packaging information, and other details will be sent on request.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Chicago, Cleveland, Houston, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, Washington. In Canada: Peacock Bros., Ltd., Montreal, Quebec.

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786	803	820	837	854	871	888	905	922	939	956	973	990	1007
787	804	821	838	855	872	889	906	923	940	957	974	991	1008
788	805	822	839	856	873	890	907	924	941	958	975	992	1009
789	806	823	840	857	874	891	908	925	942	959	976	993	1010
790	807	824	841	858	875	892	909	926	943	960	977	994	1011
791	808	825	842	859	876	893	910	927	944	961	978	995	1012
792	809	826	843	860	877	894	911	928	945	962	979	996	1013
793	810	827	844	861	878	895	912	929	946	963	980	997	1014
794	811	828	845	862	879	896	913	930	947	964	981	998	1015
795	812	829	846	863	880	897	914	931	948	965	982	999	1016
796	813	830	847	864	881	898	915	932	949	966	983	1000	1017
797	814	831	848	865	882	899	916	933	950	967	984	1001	1018
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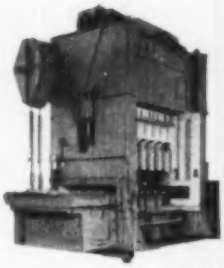
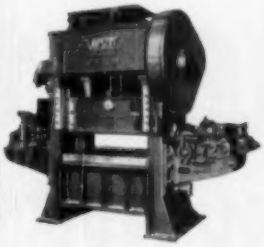


Verson Transmat Presses perform a series of consecutive operations completely automatically without intermediate handling.



Verson High Speed Presses have been made in many sizes and types for exceptionally high production requirements.

Verson Hydraulic Presses are made in all sizes and types and feature the simplified, trouble-free Hydrol circuit.

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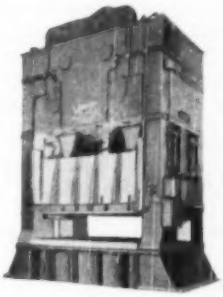

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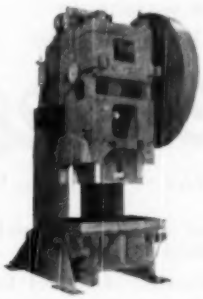
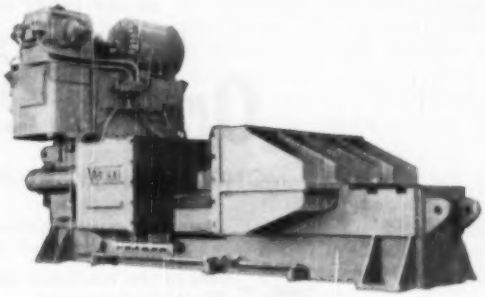


Verson Open Back Inclinable Presses are versatile, economical units, designed to handle a wide range of jobs.



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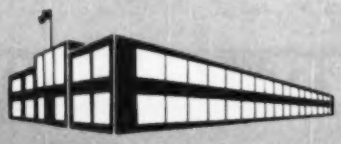

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

ANNOUNCEMENT DEFERRED

Before Korea we were planning an announcement.

We intended to present to Industry the results of seven years' research culminating in more than three years of intensive development of new casting processes.

These processes will, we believe, establish new standards for dimensional precision, cleanliness, and structural control of castings which go beyond previous concepts of the Metallurgist, Designer and Foundryman.

We are proud of the results we have obtained. We believe that responsible Engineers and Metallurgists will concur in the approval that has been voiced by more than two hundred representatives of leading companies who have viewed some phases of the work.

Because many phases of our work have been sponsored by the U. S. Navy on non-profit contracts (some of which has been reported in the Technical Press), we have, voluntarily, reserved our limited personnel, facilities, and effort for application to problems in Defense Production. General dissemination of information at this time, in advance of our ability to accept usual commercial commitments, is deemed inadvisable.

We will, however, have available at the National Metal Exposition necessary engineering personnel and descriptive matter to discuss application of our new casting processes with representatives of the Armed Services or defense contractors.

There are many items now produced as forgings or machined from mill products, ranging from rockets and jet engine components to gun mechanism, from aircraft landing gear, to valves, pumps, and projectiles, where advantages may be indicated.

Work to date clearly indicates that metals cast by these new processes and controls offer many probable economies and higher production with fewer, or less critical, facilities, and in some cases with substantial weight reduction and inherent technical advantages over contemporary processes.

Many previous concepts of castings as compared to forgings and of dimensional control, machinability, and metal soundness do not apply to these new processes. Men charged with the responsibility of design and production of defense materiel may feel that an understanding of these advanced processes is important if not obligatory in the discharge of such responsibilities.

Those men who agree "A forging is merely a casting that has had hell slapped out of it" and who concede that a casting in a ceramic mold can be *cleaner* than an ingot *casting* in a pitch-and-clay-smeared ingot mold; or, those who are acquainted with mill products made from "semi-killed" steel, will have a sound basis for evaluating these processes.

Many are aware that as-cast structures and physical properties *vary greatly* with the inherently wide *and* substantially uncontrolled pouring temperatures *inherent* in conventional foundry practice.

Designers have frequently condemned castings because of the unpredictable dirt and gas resulting from moisture and combustion of organics in molds. Users or producers of castings may concur in the opinion of many qualified observers that this work may open a new and broader field of usefulness to the American foundry industry, ferrous or non-ferrous, in the National Defense.

The projected elimination of skilled labor, inherently high yields and production rates, reduction of occupational hazards and savings in transportation offer potential economies and operating benefits to those who think in broad terms and who have the perspective to evaluate trends, obsolescence and progress.

Because our branch offices are not authorized to disseminate technical information or negotiate on new process applications, it may be mutually convenient to discuss Defense Production problems at the Metal Show. We will appreciate it if such accredited engineers as have problems to discuss will advise us in advance of their visit.

FOR 32 CONSECUTIVE YEARS

For thirty-two consecutive years, General Alloys will be the largest and only continuous alloy casting exhibitor at the ASM Show. Our history and experience parallels the growth and development of A.S.M., the automotive and aircraft industries, and the development of heat and corrosion resisting alloys. Through the years we have endeavored to evaluate our own ignorance and broaden our knowledge in this highly specialized field. It is yours for the asking, for you men of ASM have made it possible to build General Alloys.

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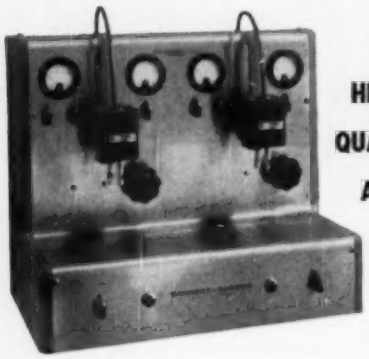

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The Sargent-Slomin Electrolytic Analyzer represents a complete re-design of the original Slomin instrument. Each unit is mounted within a case consisting of a one-piece stainless steel panel, beaker platform and apron with sturdy end castings. All models are completely self-contained and operate from 50-60 cycle electric circuits—no auxiliary generators or rheostats are required.

The two position analyzers consist of two complete, independently operating analyzer circuits. Duplicate or check analyses can be run at the same time.

The central electrode is rotated by a constant speed capacitor wound motor, operating at 550 r.p.m., especially engineered for this application.

Outstanding features of this rugged motor are:

Greater output than any motor of similar characteristics and size.

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These analyzers used with the specially designed high efficiency corrugated electrodes rapidly produce smooth, close grained deposits at maximum current density

S-29460 ELECTROLYTIC ANALYZER—Sargent-Slomin, One Position, with Heating Plate. For operation from 115 Volt, 50-60 cycle circuits $250.00

S-29465 ELECTROLYTIC ANALYZER—Sargent-Slomin, Two Position, with Heating Plate. For operation from 115 Volt, 50-60 cycle circuits $395.00

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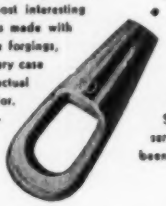

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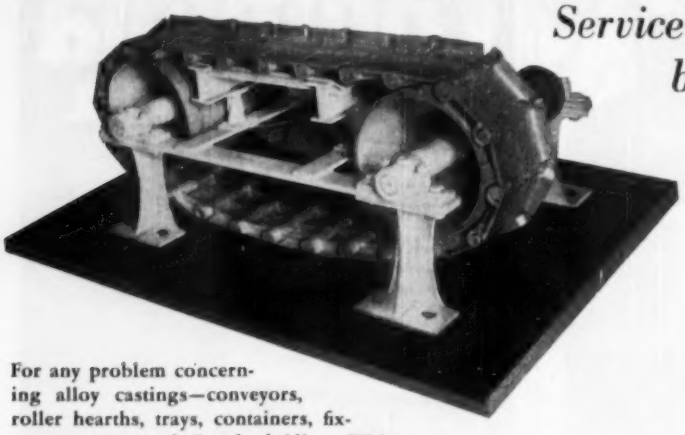

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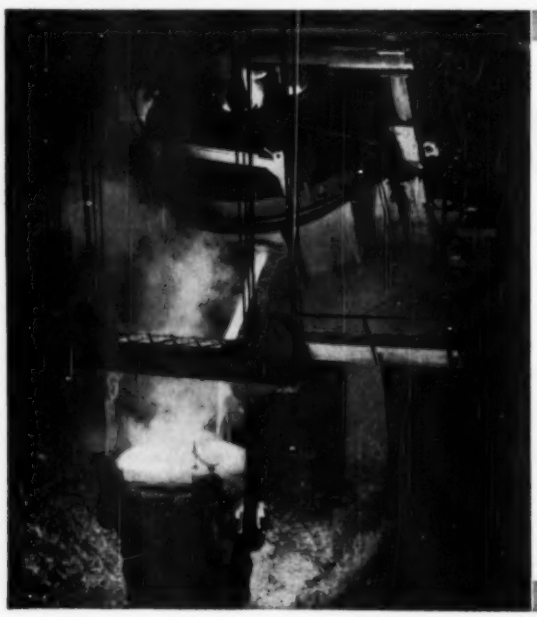

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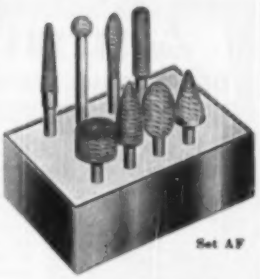

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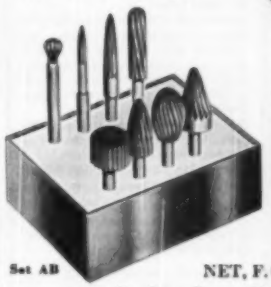

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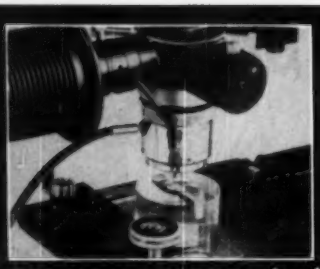

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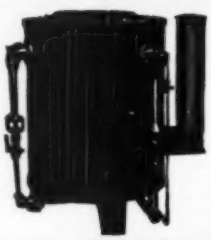

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¼" " " " "	3 seconds
½" " " " "	15 seconds
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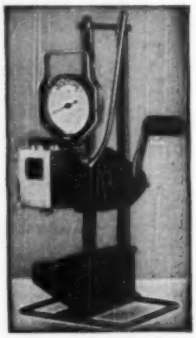

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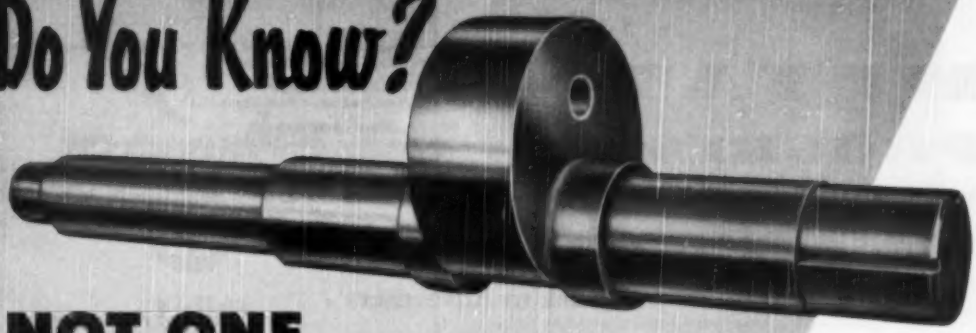

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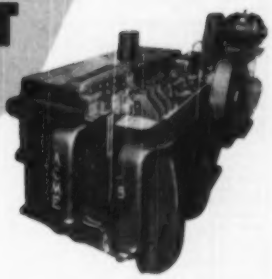

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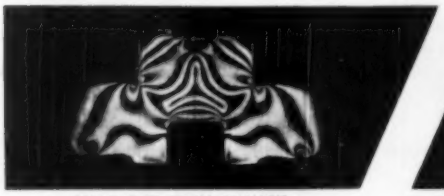

CRANK TYPE STRESS ANALYSIS

ECCENTRIC TYPE STRESS ANALYSIS

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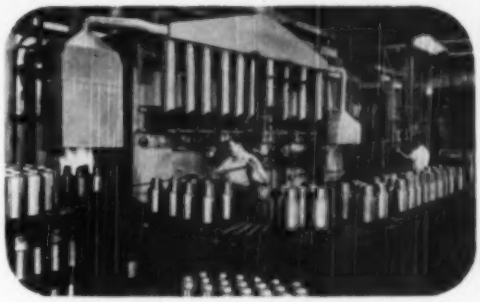

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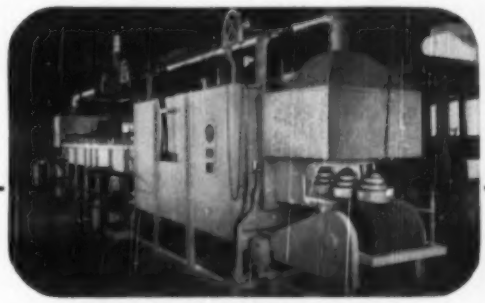

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